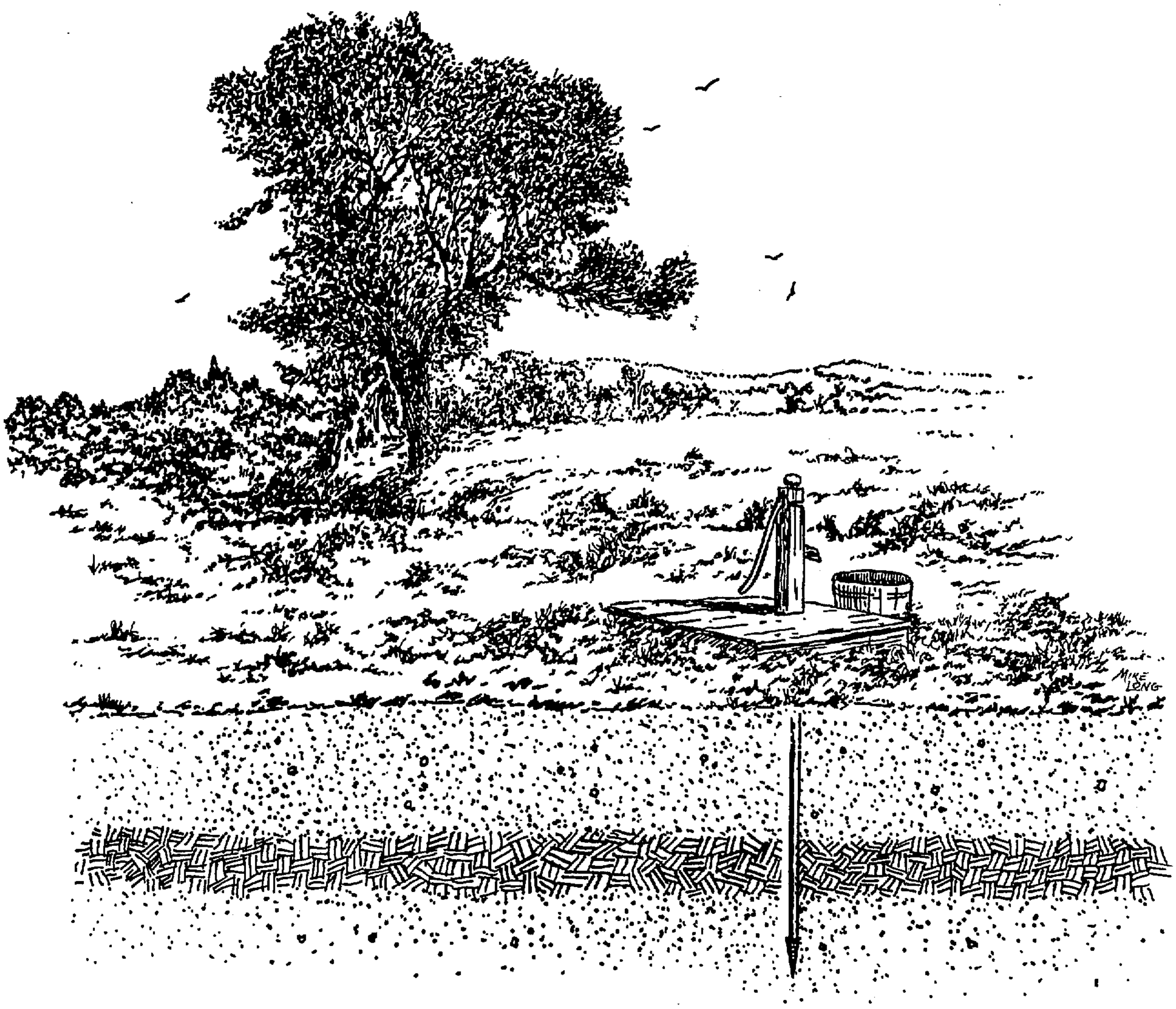
GROUNDWATER PROTECTION HANDBOOK

FOR

SOUTHEASTERN VIRGINIA



PREPARED BY SOUTHEASTERN VIRGINIA PLANNING DISTRICT COMMISSION

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Southeastern Virginia Planning District Commission

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EXECUTIVE SUMMARY

In response to a growing awareness of the vulnerability of groundwater to contamination from human activity, the Virginia Groundwater Protection Steering Committee (GWPSC) was formed in 1985. In 1986, the GWPSC completed A Groundwater Protection Strategy for Virginia which calls upon local governments to become more involved in groundwater protection. The 1988 Virginia General Assembly enacted legislation giving local governments the authority to consider groundwater protection in preparing local comprehensive plans and zoning ordinances.

A Groundwater Protection Handbook for Southeastern Virginia is designed to improve the coordination and quality of local decision making as it relates to groundwater protection. The Handbook will assist local governments in implementing the recommendations of the State Groundwater Protection Strategy, and in assuming the powers and responsibilities granted under the 1988 enabling legislation.

WHAT IS GROUNDWATER AND WHY IS IT THREATENED?

The Handbook includes an overview of groundwater hydrogeology, groundwater use and potential sources of contamination.

In 1988, there were more than 800 documented cases of groundwater contamination in Virginia and new cases were occurring at a rate of twelve per month. Most of these cases are attributable to leaking underground storage tanks and associated piping.

It is commonly believed that physical and chemical processes attenuate contaminants as they infiltrate through the soil. However, attenuation may be incomplete or nonexistent and the underlying aquifers may be contaminated. Contaminants may go undetected for many years and become evident only when they reach a discharge point, usually a well. By that time, the source of the contaminant may be difficult to determine.

The degree to which groundwater becomes contaminated will depend on local hydrogeology, the volume and composition of contaminants, and the effects of local well pumping on groundwater flow. Once groundwater is contaminated, remedial efforts can be expensive and it is usually impossible to return groundwater to its former potability. The health and economic costs to a community from contamination can be extremely high. It is therefore imperative that efforts be undertaken to protect groundwater before contamination occurs.

THE HYDROGEOLOGY OF SOUTHEASTERN VIRGINIA

Southeastern Virginia's groundwater system lies in the Coastal Plain and consists of a seaward-thickening wedge of unconsolidated sediments containing seven confined aquifers and one water table aquifer. Natural groundwater flow through the confined aquifer system is in a lateral, seaward direction while flow within the water table aquifer generally follows topography. Natural discharge occurs at streams, lakes, the Chesapeake Bay and the Atlantic Ocean. The largest source of aquifer recharge is vertical leakage from the water table aquifer to the confined system. Natural flow, has been disrupted by pumping in some areas.

REGIONAL GROUNDWATER USE

The USGS estimates that groundwater withdrawal from the region's confined aquifers averaged 57.5 million gallons per day (MGD) in 1986. Withdrawals from the water table aquifer were not included in this estimate. One industry alone, the Union Camp Corporation near Franklin, accounted for 59 percent of the total. Overall, industry accounted for 74.1 percent and public water suppliers accounted for 25.4 percent of withdrawal. Total regional withdrawal allowed under VWCB permits is 160.18 MGD.

Steadily increasing pumping of groundwater in the deeper confined aquifers since the turn of the century has resulted in significant water level declines, expanding cones of depression, and potential contamination by saltwater intrusion. The most significant water level decline is centered on the city of Franklin. There has also been a proliferation of domestic wells which tap the shallower aquifers. This, in combination with increases in the number of water-to-air heat pumps and in the amount of impervious surface, has lead to a significant drop in water levels in developed areas. It is speculated that this has caused salt water encroachment and well contamination in some areas.

GOVERNMENT'S ROLE IN PROTECTING GROUNDWATER

Until the mid-1970s, federal water quality management efforts focused primarily on surface water. In the mid to late 1970s, however, groundwater contamination problems became better understood and pressure was exerted on the federal government to take a more active role in protection efforts. Direct federal involvement in groundwater protection was first evident in the Safe Drinking Water Act (SDWA) of 1974. Several other federal statutes, enacted in the 1970s, also address threats to groundwater. Because groundwater protection was being addressed through a number of programs designed for different purposes, the EPA adopted a Groundwater Protection Strategy in 1984. This Strategy is designed to coordinate federal regulatory programs and strengthen state programs.

Because there is no comprehensive federal statute requiring states to develop programs that are specifically related to groundwater protection, approaches to protecting groundwater differ from state to state. In Virginia, the legal mandate to protect groundwater lies in the Virginia Constitution which declares that it is the policy of the Commonwealth to protect all State waters, including groundwater, from degradation. The State Water Control Law (SWCL) was enacted to carry out this mandate. The SWCL contains an "anti-degradation" policy which provides for the protection of all high quality waters, and for the restoration of all other waters to a level of quality that will permit all reasonable uses and support aquatic life. Based on the anti-degradation policy and the State's groundwater quality standards, the GWPSC concluded that there is no right to degrade groundwater from its natural quality; no groundwater is pre-classified to allow degradation; those responsible for groundwater pollution can be required to restore the water to its natural condition; and groundwater protection activities must take social and economic consequences into account.

Although the Virginia State Water Control Board has primary responsibility for groundwater protection, several other State agencies administer groundwater management programs. Since publication of A Groundwater Protection Strategy for Virginia, a number of the Strategy's recommendations as well as other State groundwater protection initiatives have been implemented.

Decisions made by local governments have the greatest potential to impact groundwater quality. Ironically, Virginia's locality's have been least involved in groundwater protection. Reasons for this include the State's reliance on the Dillon Rule, regulatory preemption by State and federal statutes, and lack of awareness and information. Several provisions of the SDWA and Virginia's new solid waste disposal facility regulations require more involvement by localities.

GROUNDWATER QUALITY PROBLEM AREAS IN SOUTHEASTERN VIRGINIA

The overall natural quality of the region's groundwater is high. High chloride levels, however, are present in the deeper aquifers in the eastern portion of the region and in the shallower aquifers in the vicinity of tidal waters. Other sporadic, naturally occurring groundwater quality problems include high fluoride and sodium levels in the deeper aquifers, and high iron levels and high acidity in the shallower aquifers.

Large-scale, human-induced contamination of the region's aquifers is not a problem. However, the region has experienced a number of localized groundwater contamination incidents in which finite areas near specific sources of pollutants have been affected. Based on a review of literature and VWCB records, and interviews with local officials, there are seven high priority threats to groundwater in Southeastern Virginia. These are septic systems, underground storage tanks, spills and improper disposal of hazardous materials, surface waste impoundments, landfills, pesticide and fertilizer applications, and saltwater encroachment. Known and suspected groundwater contamination problems in Southeastern Virginia attributable to these sources are discussed. Officials involved in local groundwater management believe that contamination is more prevalent than existing information indicates.

It is not within the scope of this Handbook to conduct a regional analysis of local hydrogeologic factors to determine areas that are particularly susceptible to groundwater contamination. Such an analysis could be conducted using the DRASTIC mapping methodology. The Handbook describes and evaluates the DRASTIC methodology and it potential for use in Southeastern Virginia.

It is also important to identify specific sources which have a high potential for causing contamination. Through the use of site-specific source evaluations, high risk land use activities are identified, located and mapped, compared with the location of sensitive areas, and assigned hazard rankings. A methodology developed by the West Michigan Shoreline Development Commission is described.

In humid areas, such as Southeastern Virginia, groundwater discharge may account for 70 percent to 80 percent of a stream's annual discharge. Consequently, if contaminated, groundwater discharge to surface waters may pose a threat to environmentally critical aquatic areas. Also, depletion of groundwater supplies can increase concentrations of pollutants by reducing flow. In Southeastern Virginia, there have been a number of documented or suspected incidents of the degradation of surface water by contaminated groundwater.

LOCAL GROUNDWATER PROTECTION TECHNIQUES

For a community to develop an effective groundwater protection program, it must prepare a groundwater management plan consisting of community-specific goals and objectives, and locally appropriate management techniques. These should reflect local groundwater protection needs. Specific management techniques should be combined to maximize effectiveness and minimize costs.

In describing and evaluating groundwater protection techniques, this Handbook makes a distinction between sensitive area controls and source controls. Discussion is limited to those techniques that would protect the region's two shallowest aquifers: the Columbia (water table) and Yorktown-Eastover. This is because they are the most susceptible to contamination and serve as the principal source of recharge to the region's deeper aquifers. In addition, State regulations ban the use of underground injection wells for waste disposal, thus protecting the deeper aquifers from the direct introduction of pollutants.

Sensitive area controls involve the application of land use management techniques to locations where groundwater resources are the most vulnerable to contamination. Sensitive area groundwater protection controls might include the incorporation of traditional or innovative techniques into zoning ordinances; the incorporation of groundwater protection provisions into other land use control ordinances; land acquisition; and tax incentives. Innovative zoning techniques described and evaluated in this Handbook include overlay zoning, Planned Unit Development, transfer of development rights, and performance standards. Other land use regulations that might be revised to protect groundwater include subdivision, erosion and sediment control, site plan review and stormwater management ordinances. Land acquisition strategies might include fee simple purchase, purchase of development rights, or purchase of restrictive easements. Use-value taxation might be used for land dedicated to protecting groundwater supplies.

A number of specific source controls are identified and evaluated for those contamination sources that have been determined to pose the greatest threat to the region's groundwater supply. Most of these sources are already subject to State and federal regulations. A locality may decide, however, that existing regulations do not adequately address community-specific contamination threats. Source controls discussed in this Handbook include education programs, and local regulations which exceed or supplement federal and State regulations for the siting, design, operation and maintenance of potential contamination sources. Other controls are aimed at keeping potential contaminants from entering the environment. These include recycling of wastes, the extension of public sanitary sewer lines to areas served by septic systems, the extension of public water lines to areas experiencing pumping induced saltwater encroachment, and the use of Integrated Pest Management.

MODEL GROUNDWATER PROTECTION REGULATIONS

Outlines for regulations that might be used to implement a local groundwater protection plan are presented. They include new septic system and hazardous material ordinances, and amendments to existing zoning, subdivision, erosion and sediment control, site plan review and stormwater management ordinances. Due to the diversity of potential contamination sources within a community, and because contamination threats and protection needs can differ significantly among communities, it was deemed impractical to develop a single, comprehensive model groundwater protection ordinance.

Careful consideration must be given to local capability to implement the model regulations presented in this Handbook. The studies necessary to adapt the regulations to local conditions, and the review, monitoring, inspection and enforcement provisions contained in the regulations are likely to require increases in funding for staff, training and equipment. It is important to coordinate groundwater protection activities with other management programs wherever possible. Groundwater protection initiatives may also be of benefit in achieving stormwater management and SARA Title III objectives. Local Chesapeake Bay Preservation Act programs may be used as vehicles for the implementation of groundwater protection strategies. Finally, it is important to involve all entities with groundwater use and/or protection concerns in the planning implementation of a local groundwater protection program. This might be done by creating a groundwater protection council or task force.

INTRODUCTION

Groundwater* plays an important role in Southeastern Virginia's economy and quality of life. Many of the region's industries, businesses, municipalities and households depend on groundwater for their water supply needs. The region's dependence on groundwater has grown significantly in recent years due to increased water consumption by a rapidly growing population and a thriving economy, and to economic, environmental and political constraints which have hindered the development of surface water supplies. Past planning efforts have centered on groundwater quantity management. More recently, however, there has been a growing awareness of the vulnerability of groundwater to contamination by human activity.

In response to the growing concern for groundwater quality and with encouragement from the U.S. Environmental Protection Agency (EPA), the State of Virginia formed the Virginia Groundwater Protection Steering Committee (GWPSC) in 1985. The GWPSC is chaired by the Virginia State Water Control Board (VWCB) and consists of representatives from agencies whose programs can affect groundwater quality. In 1986, the GWPSC completed <u>A Groundwater Protection Strategy for Virginia</u>. This Strategy includes a number of recommendations to improve groundwater quality management throughout the state. Many of these recommendations call upon local governments to become more involved in groundwater protection.

In 1988, the Virginia General Assembly implemented two of the recommendations contained in the State Groundwater Protection Strategy by passing bills which increase local powers to promote groundwater quality management. These bills amended the Virginia Code by granting local governments the authority to consider groundwater protection in the local planning process. Section 15.1-446.1 of the Code was amended to add both surface and groundwater protection to the list of items that may be considered in preparing a local comprehensive plan, and Section 15.1-489 was amended to require local governments to consider groundwater protection in the preparation of local zoning ordinances. The 1988 General Assembly also passed the Chesapeake Bay Preservation Act (CBPA) which reinforced these bills by authorizing Virginia localities to consider all aspects of water quality protection in developing any land use regulations.

The main objective of <u>A Groundwater Protection Handbook for Southeastern Virginia</u> is to improve the coordination and quality of local and regional decision-making as it relates to groundwater protection. To meet this objective, the Handbook assists local governments in implementing the locally-oriented recommendations of the State's Groundwater Protection Strategy, and in assuming the newly authorized local powers and responsibilities granted under 1988 enabling legislation. Specifically the Handbook will include the following:

*All words and phrases in bold print and all acronyms are defined in the Glossary.

- A general discussion of what groundwater is, how it is formed and how it can be contaminated.

- A description of Southeastern Virginia **hydrogeology** and groundwater usage and a discussion of federal, State and local responsibilities in protecting groundwater.

- A determination of areas of concern in Southeastern Virginia including known and suspected groundwater contamination problems and areas that are susceptible to groundwater contamination.

- An inventory and evaluation of groundwater protection techniques.

- Recommendations for local groundwater protection regulations including outlines for new ordinances and suggested modifications to existing ordinances.

WHAT IS GROUNDWATER AND WHY IS IT THREATENED?

THE HYDROLOGIC CYCLE

Groundwater owes its existence to the continual movement and recycling of water above, on and under the earth's surface. This process is known as the **hydrologic cycle**. As is illustrated in Figure 1, the fundamental stages of the hydrologic cycle include (1) the transfer of water into the atmosphere by evaporation from surface waters and by **evapotranspiration** from land areas; (2) the transport of water through the atmosphere in the form of clouds; and (3) the return of water to the earth's surface by precipitation. Once returned to the earth through precipitation, the movement of water can take several routes. It can be temporarily stored on vegetation or in surface depressions and then quickly evaporated. It may also run off the surface of the land to the nearest water body. Most importantly with respect to groundwater, it may enter, or **infiltrate**, the soil. Once the upper layer of the soil becomes moist, water **percolates** deeper through the **soil** and **unsaturated zones** until it reaches a **saturated zone** where it is stored as groundwater. Groundwater then moves through the saturated zone and, in Southeastern Virginia, eventually discharges to surface water. This process may take several days or several decades depending on local conditions.

BASIC HYDROGEOLOGY

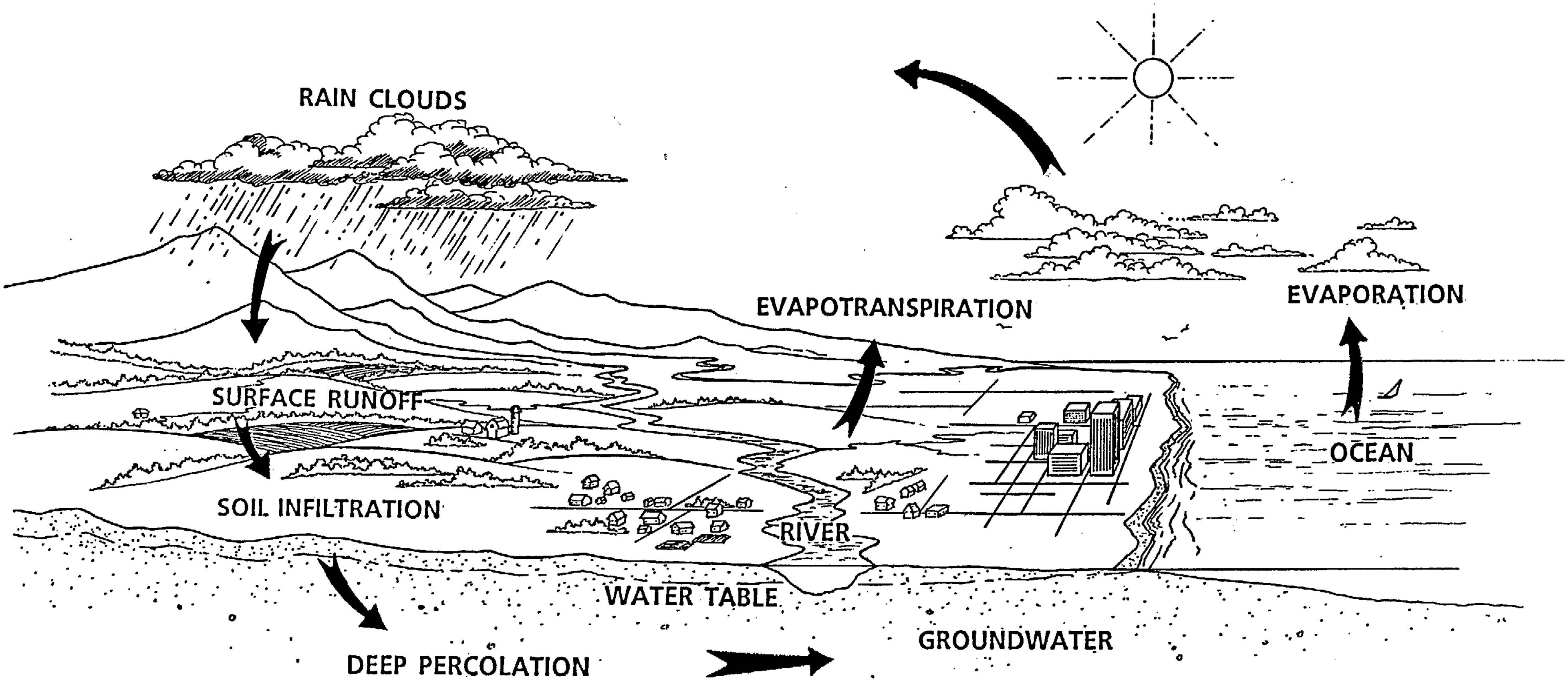
Groundwater is not, as is sometimes believed, found in underground rivers or lakes. Instead, it is found in water bearing geologic formations that comprise the saturated zone. It is estimated that in the top kilometer of the earth's crust there is thirty times more water than is found in all of the earth's freshwater rivers, lakes and streams. Water bearing geologic formations can consist of either **unconsolidated** or **consolidated** materials. Unconsolidated formations are composed of deposits of loose sand, gravel, rock, shell or soil. Groundwater is stored within the void spaces, or pores, of these deposits. Consolidated formations are comprised of solid rock masses. Groundwater in these formations is stored in cracks, fissures, channels, or in porous rock such as limestone.

Water bearing geologic formations that will yield usable quantities of water to wells or springs are known as **aquifers**. Aquifers can either be **unconfined** or **confined**. Unconfined aquifers occur where unsaturated porous material overlies an aquifer. The top boundary of the unconfined aquifer, commonly known as the **water table**, will rise and fall as the quantity of water in the aquifer fluctuates. The water table generally follows the slope of the land flowing from higher to lower elevations. Unlike confined aquifers, water in unconfined aquifers remains at atmospheric pressure.

Confined aquifers are sandwiched between impermeable or semi-permeable rock or soil formations known as **aquitards**. The difference in height between the higher and lower portions of a confined aquifer may result in considerable pressure

FIGURE 1

THE HYDROLOGIC CYCLE



Source: Adapted from Virginia Water Resources Resources Research Center, Threats to Virginia's Groundwater, (Blacksburg, Virginia: VWRRC, 1988), p. 3.

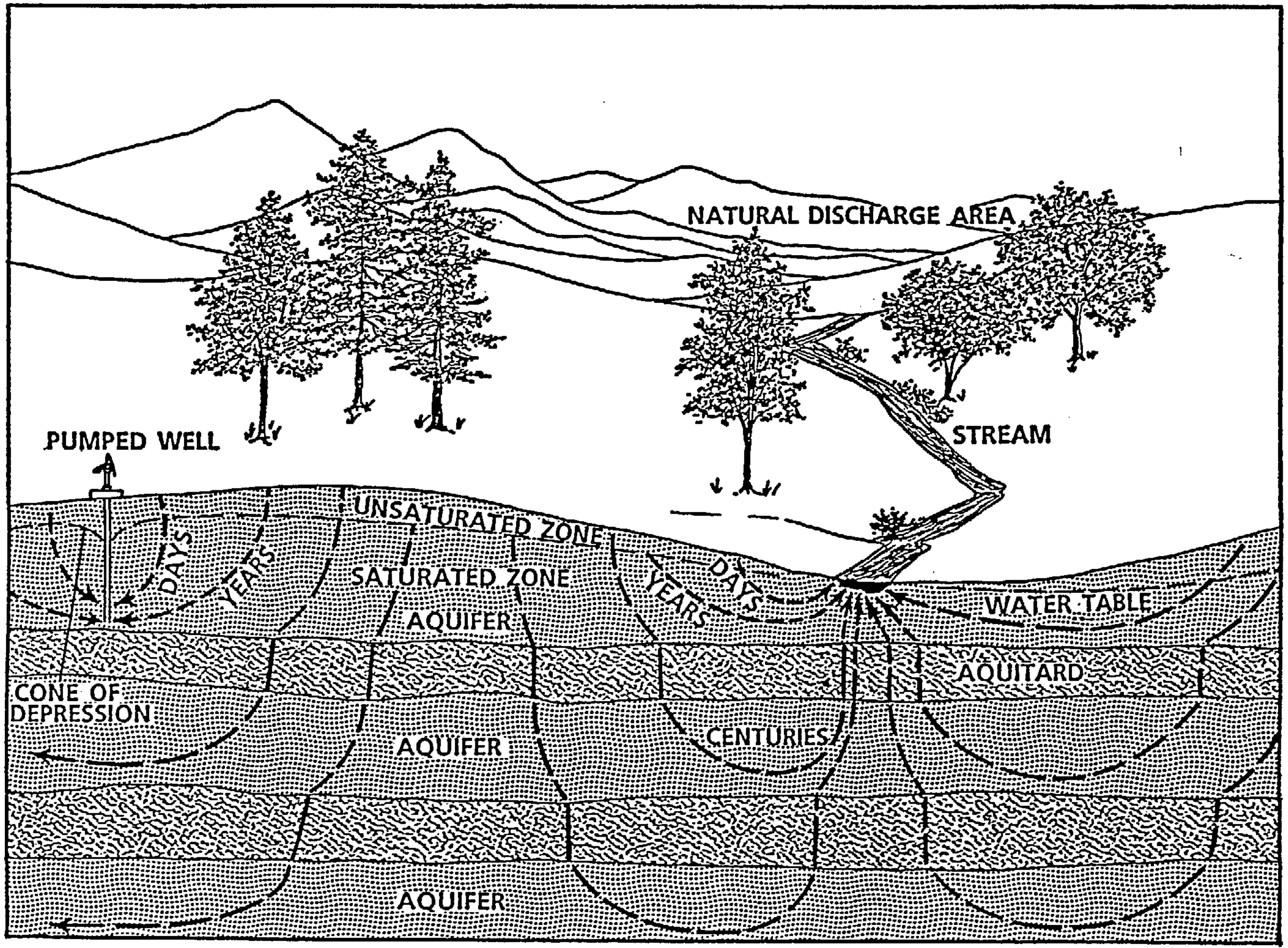
differential. Therefore, if a well is drilled in the lower end of a confined aquifer, water will rise above the level of the overlying aquitard. The level to which water would rise in a well drilled into a confined aquifer is called the **potentiometric**, or **piezometric**, surface. If the potentiometric surface is above ground level, the well is called a flowing **artesian well**. A cross-section showing typical unconfined and confined aquifers and generalized groundwater flow can be found in Figure 2.

The capacity of an aquifer to store and transmit water depends on the **porosity** and the **permeability** of the materials comprising it. Porosity is the ratio of pore space to the total volume of material. Porosity values, which are a function of the size and shape of pores, indicate the maximum amount of water that a formation can contain when fully saturated. Typical permeability is a measure of an aquifer's ability to transmit water. Permeability is a function of the size of the pores and cracks within a formation and the extent to which they are interconnected. Permeability values, expressed in feet of groundwater movement per day, for various geologic materials are shown in Table 1. A high permeability value is generally required for a productive groundwater well. It is possible for a water bearing formation to have high porosity but low permeability, and vice versa. For example, a clay deposit will have many small pores and will thus hold more water than a sand deposit that has fewer but larger pores. However, the size of the pores and the fact that they are highly interconnected gives sand a much higher permeability value and makes a sand aquifer a more productive source of groundwater. Wells drilled into clay deposits, or other formations with low permeability values, will produce little or no water despite the presence of large supplies.

The process by which water is added to an aquifer is known as **recharge**. Recharge may occur from rain water infiltration, from seepage from lake bottoms or stream beds, or from replenishment from overlying or underlying aquifers as a result of hydraulic pressure differential (also known as induced recharge). Any removal of water from an aquifer is known as **discharge**. Discharge points include wells, springs, streams, lakes or wetlands. The surface area from which water for an aquifer is collected is called the **recharge area**. In the eastern United States, where precipitation usually exceeds evapotranspiration, recharge of aquifers generally exceeds discharge. Because water percolates both vertically and horizontally through an aquifer, the principal recharge area for that aquifer may be hundreds of miles from the point of water withdrawal. Therefore, local precipitation and land use at the point of withdrawal does not necessarily govern the recharge rate and water quality of an aquifer.

FIGURE 2

GENERALIZED GROUNDWATER SYSTEM



Source: USGS, Office of Technology Policy, <u>Federal Groundwater Science and Technology Programs</u>, (Washington, D.C.: USGS, 1989), p. 3-1.

TABLE 1

TYPICAL PERMEABILITY VALUES

Material	Permeability (feet/day)
Gravels	280 to 2,800
Sands	60 to 450
Silts	0.5 to 0.8
Silty Sand	0.03 to 280
Glacial Till	0.0000003 to 0.3
Clays	0.00004
Sandstone	0.01 to 11
Shale	0.002 to 0.009

Note: Permeability values reflect the capacity of a material to transmit water. Actual rate of water movement within an aquifer may be different.

Source: VanderMeulen and Reinking, Groundwater and Transition Landfills, (Kalamazoo, Michigan: Western Michigan University, Science Citizens Center, 1982).

THREATS TO GROUNDWATER

Through a variety of human activities, pollutants may be allowed to enter the ground and threaten groundwater supplies. The U.S. Office of Technology Assessment has identified over 200 groundwater contaminants related to land use activity. These contaminants can be classified into three general categories: (1) bacteria and viruses; (2) nitrates, heavy metals, minerals and salts; and (3) **synthetic organic compounds**.[1] Potential sources of groundwater pollution in Southeastern Virginia and the types of pollutants generally associated with these sources are listed in Table 2. Figure 3 is a schematic representation of land use activities that may contaminate groundwater.

As of 1988, there were more than 800 documented cases of groundwater contamination in Virginia and new cases were occurring at a rate of twelve per month.[2] Most of these cases are attributable to leaking underground storage tanks and associated piping. Other documented sources of contamination by frequency of occurrence include landfills, **surface impoundments**, septic systems and agricultural activities.

Contrary to common belief, groundwater is not always cleansed of contaminants as it infiltrates through the soil and unsaturated zones. The infiltration process can **attenuate** some wastes through a number of physical and

TABLE 2

POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION IN SOUTHEASTERN VIRGINIA

SOURCE	Pathogens[1]	Nitrates	Heavy Metals	Salts and Minerals	Organic Chemicals
	Contaminant				
Septic systems	X	X	X	X	X
Land application of sewage treatment wastewater and sludge	X	X	X	X	X
Land application of animal manure	X	X			
Sanitary landfills			X	X	X
Hazardous waste handling facilities			X		X
Abandoned hazardous waste sites			X		X
Illegal dumping[2]			X	X	X
Surface waste impoundments (ponds, pits, lagoons)	X	X	X	X	X
Outside materials storage			X	X	X
Dead animal burial	X				
Above- and underground storage tanks			X	X	X
Pesticide applications					X
Fertilizer application		X		X	
Animal confinement and feeding operations	X	X	X		X
De-icing applications				X	
Urban runoff	X	X	X	X	
Settling of atmospheric pollutants			X	X	

TABLE 2 (Continued)

POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION IN SOUTHEASTERN VIRGINIA

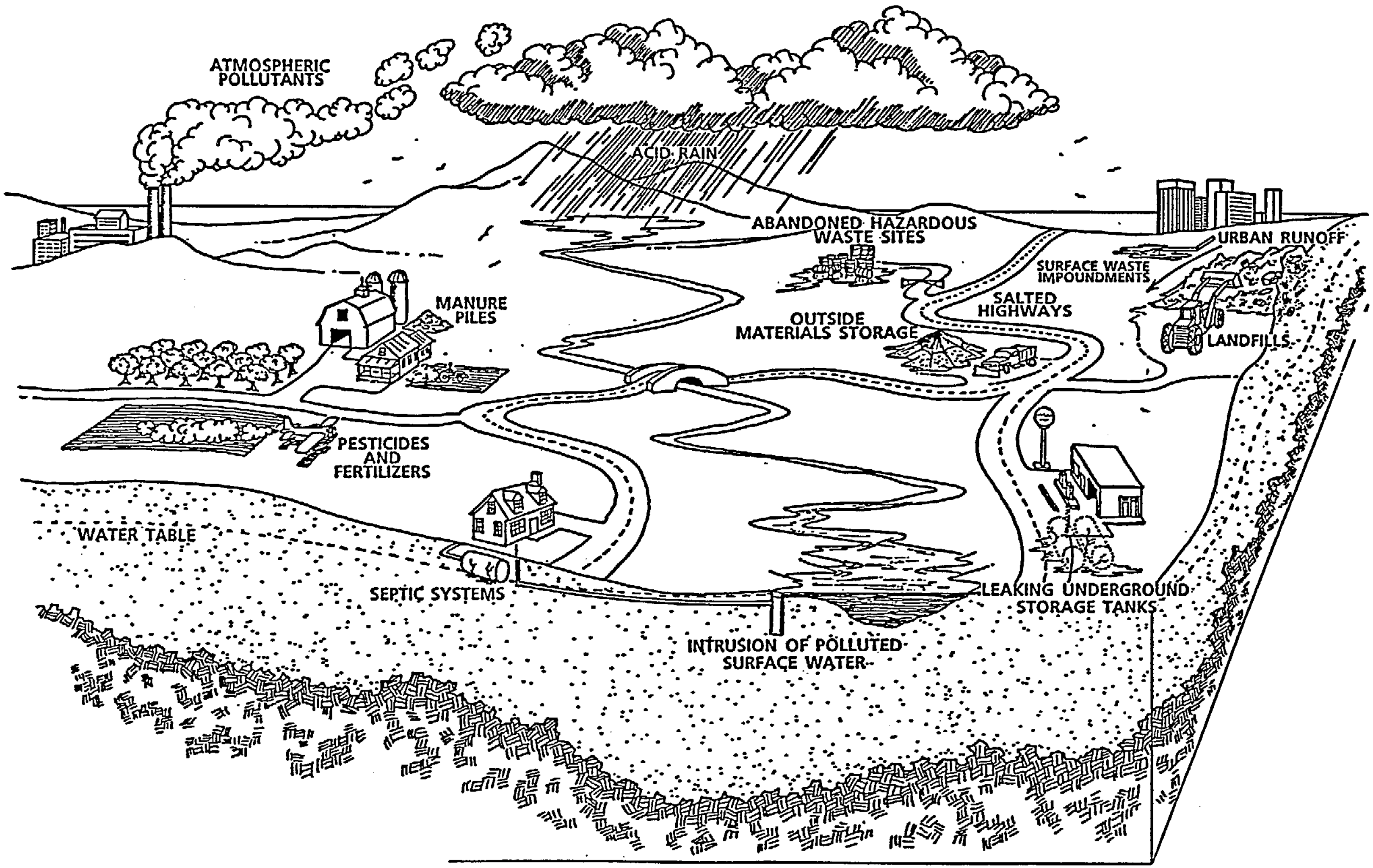
SOURCE	Pathogens	Nitrates	Heavy Metals	Salts and Minerals	Organic Chemicals
	Contaminant				
Sanitary sewer systems	X	X	X	X	X
Petroleum pipelines			X		X
Spills during transport of hazardous materials			X	X	X
Artificial recharge[3]	X		X	X	X
Intrusion of polluted surface waters	X	X	X	X	X
Salt water encroachment from over-pumping				X	
Naturally occurring sources		X	X	X	

Notes:
1. Includes bacteria, viruses and parasites.
2. Includes promiscuous dumping of hazardous and non-hazardous waste by industries, businesses and households.
3. Includes recharge of aquifers to enchance groundwater supplies, heat pump exchange wells and stormwater infiltration devices.
4. Includes natural leaching and natural groundwater and surface water interactions.

Source: Southeastern Virginia Planning District Commission, 1989.

FIGURE 3

LAND USE ACTIVITIES THAT MAY CONTAMINATE GROUNDWATER



Source: Commonwealth of Massachusetts, Groundwater Quality and Protection: A Guide for Local Officials, (Boston Massachusetts; 1982), p. 20.

chemical processes including **filtration, sorption, oxidation** and **reduction, biological decay and assimilation, dilution, buffering** of acidic and alkaline materials, **chemical precipitation, volatilization, evaporation,** and **radioactive decay**.[3] Nevertheless, attenuation of many contaminants may be incomplete or nonexistent and contamination of underlying aquifers may occur. This is particularly likely where soil conditions allow for rapid infiltration or where an aquifer lies close to the surface. In some cases, contaminants may be introduced directly into an aquifer without the benefit of infiltration. This happens where septic systems, landfills or leaking underground storage tanks sit below a high water table. It may also occur as a result of the illegal injection of pollutants into abandoned wells or the leakage of pollutants into inadequately constructed wells. An inadequately constructed well may serve as a conduit for the inadvertent transfer of pollutants from the water table aquifer to confined aquifers. Because the various processes responsible for removing contaminants during infiltration are much less effective in the saturated zone, contaminants are less likely to be attenuated while moving through an aquifer. In addition, depending on the permeability of an aquifer, a plume of contaminants may take decades or even centuries to move through an aquifer.

Problems arise when polluted groundwater is withdrawn for human use or is naturally discharged into surface waters. Because contaminant plumes often move slowly through an aquifer, they may go undiscovered for many years and become evident only when they reach a discharge point, usually a well. By that time, the source of contamination may be forgotten, thus making the size and direction of the plume difficult to determine.

Groundwater contamination may be complicated by excessive pumping from an aquifer. If surface water within a recharge area is polluted, it may be drawn into a depleted aquifer. Also, excessive pumping may expand the **cone of depression** (the decline in water level in the vicinity of a well) to take in sources of contamination not included in the original cone of depression.

The degree to which groundwater contamination occurs will depend on a number of factors including soil permeability; depth to water table; rates of evaporation and precipitation; the geochemical characteristics of substrate materials; and the volume and chemical composition of wastes. Once groundwater becomes contaminated, remedial efforts are very expensive and it is usually impossible to return groundwater to its former potability. The costs to society of groundwater contamination can be extremely high. A variety of health problems have been associated with exposure to contaminated groundwater including cancers, liver and kidney damage, and disorders of the central nervous system. Because of the interrelationships among environmental media, the environmental impacts associated with contaminated groundwater may include degradation of surface water, soil, and even local air quality. The economic costs associated with groundwater contamination include not only the expense of corrective action, but also decreases in agricultural and industrial productivity, lower property values, damage to plumbing and appliances, and the costs of developing alternative water supplies.[4] Appendix A provides examples of direct economic damages incurred by communities as a result of groundwater contamination. Unless otherwise noted, the costs of remedial activities are not included. It must be emphasized that the direct costs presented in these examples were incurred over the last 25 years and are not in constant dollars. If presented in 1989 dollars, these costs would be significantly higher.

Given the potentially adverse effects of groundwater contamination, it is imperative that efforts be undertaken to protect groundwater before contamination occurs. To do this, local governments must focus their planning efforts on protecting areas that are geologically susceptible to groundwater contamination and on controlling activities that pose the greatest threat to groundwater.

THE HYDROGEOLOGY OF SOUTHEASTERN VIRGINIA

GENERAL DESCRIPTION

Southeastern Virginia lies within Virginia's Coastal Plain. The **Coastal Plain** extends from the edge of the Continental Shelf, about 100 miles offshore, to a point about 110 miles inland known as the **Fall Line** (see Figure 4). The Fall Line is an imaginary north-south line where abrupt changes in geology and elevation mark the transition between the Coastal Plain and the Piedmont Plateau. The Coastal Plain consists of a seaward-thickening wedge of unconsolidated sediments which rests on a massive body of hard rock called the **Pre-Cretaceous Basement Complex**. This wedge, consisting of alternating beds of various mixtures of sand, gravel, shell rock, silts and clays, varies in thickness from a "featheredge" at the Fall Line to approximately 3,000 feet deep along the Atlantic coast (see Figure 5).

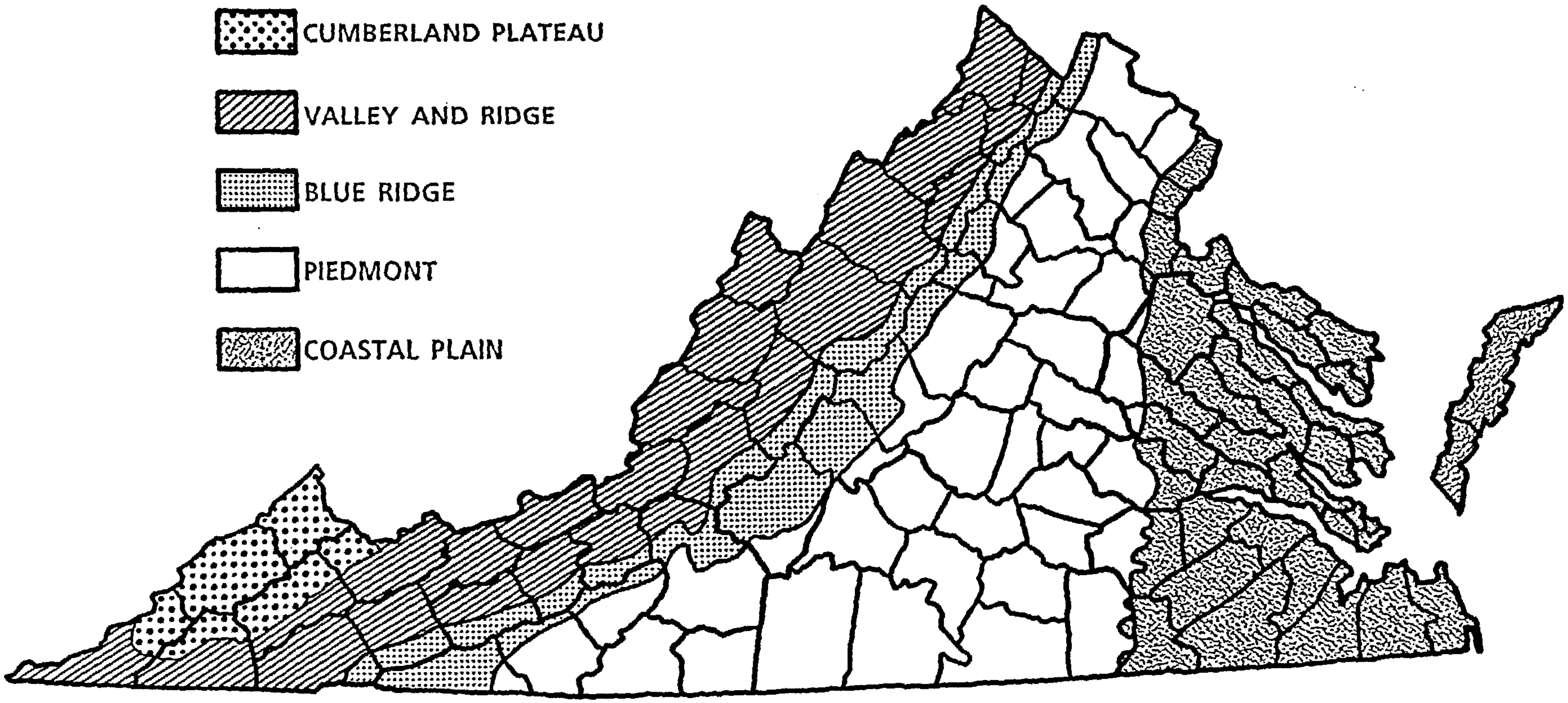
As shown in Figure 5, the groundwater system of Southeastern Virginia is comprised of one water table aquifer and seven confined aquifers. In 1979, it was estimated that the 3,000 square mile Southeastern Virginia Groundwater Management Area (SVGMA), which encompassed the Southeastern Virginia Planning District, contained 122 trillion gallons of groundwater.[5] The SVGMA was originally designated in 1976 by the Virginia State Water Control Board under the Groundwater Act of 1973 in response to significant increases in groundwater withdrawals. Encompassing an area significantly larger than the 2,018 square-mile Southeastern Virginia Planning District, the SVGMA included Surrey, Isle of Wight, Prince George and Southampton counties; parts of Greensville, Sussex and Dinwiddie counties; and the cities of Virginia Beach, Suffolk, Chesapeake, Portsmouth, Norfolk, Hopewell and Franklin. In 1989, the SVGMA was renamed the Eastern Virginia Groundwater Management Area and was expanded to include the counties of Charles City, James City, King William, New Kent and York; portions of Chesterfield, Hanover and Henrico counties; and the cities of Hampton, Newport News, Poquoson and Williamsburg.

The characteristics of Southeastern Virginia's seven confined aquifers are consistent with the geologic formation of the Coastal Plain in that most thicken and dip from west to east. Consequently, under natural conditions, groundwater flows through these aquifers in a lateral and seaward direction and discharges to a variety of points including springs, streams, lakes, the Chesapeake Bay and the Atlantic Ocean. Natural flow, however, has been disrupted by heavy pumping in some aquifers. Where this has occurred, flow patterns are radial and centered on the source of the pumping.

The region's seven confined aquifers are generally composed of various mixtures of sand, clay, silt, gravel and shell material. Recharge of these aquifers occurs from (1) infiltration of precipitation on **outcrop areas** along the Fall Line, (2) seepage from water-bearing fractures in bedrock along the Fall Line, (3) vertical discharge to and vertical recharge from aquifers through semi-permeable aquitards

FIGURE 4

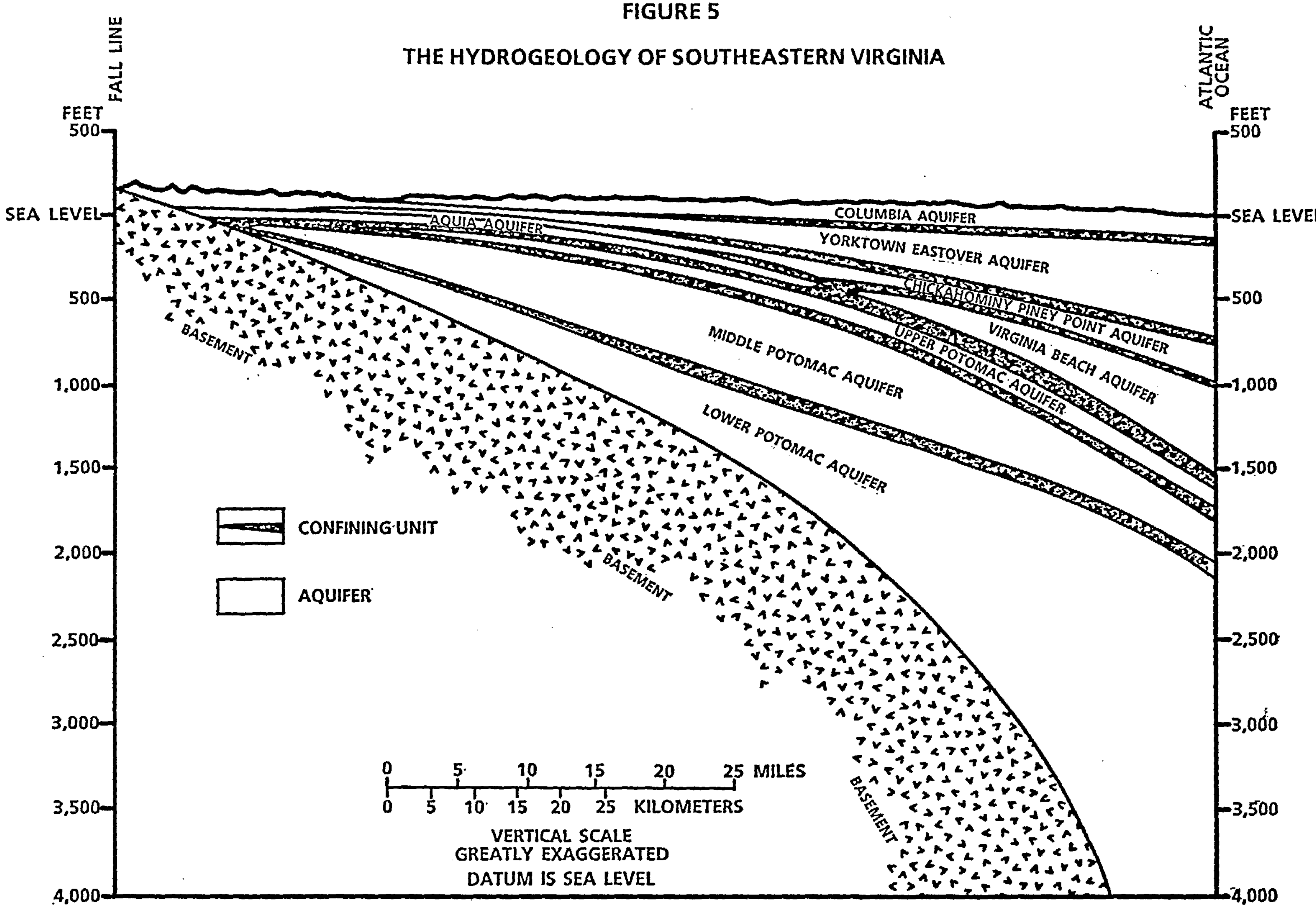
VIRGINIA'S PHYSIOGRAPHIC PROVINCES



Source: Virginia Water Research Center, <u>Threats to Virginia's Groundwater</u> (Blacksburg, Virginia: VWRRC, 1988), p. 5.

FIGURE 5

THE HYDROGEOLOGY OF SOUTHEASTERN VIRGINIA



Source: USGS, Hydrogeology and Analysis of the Groundwater Flow System in the Coastal Plain of Southeastern Virginia, (Richmond, Virginia: USGS, 1988), p. 29.

as a result of hydraulic pressure differential between the aquifers and the widely varied composition and distribution of aquitards, (4) infiltration from surface waters, and (5) vertical flow from the unconfined Columbia Aquifer to the confined system. The latter process is by far the largest source of aquifer recharge in Southeastern Virginia. Unlike regions characterized by consolidated aquifers where recharge occurs in smaller, well-defined locations, recharge to Southeastern Virginia's groundwater system can occur anywhere in the region. There are areas in the region, however, where recharge is more efficient due to a highly permeable substrate. These areas are generally found in interstream areas and along relic sand ridges. Discharge generally occurs at streams and floodplains.

Vertical flow between confined aquifers occurs because of natural hydraulic pressure differential and because aquitards of clay and silt are distributed randomly in poorly defined patterns.[6] This allows water to move upward and downward through the aquitards. Heavy pumping may accelerate this process by creating a downward hydraulic gradient that encourages vertical flow from the overlying aquifer.

THE AQUIFERS OF SOUTHEASTERN VIRGINIA

The following is a brief description of each of the aquifers found in the SVGMA. Most of the information contained in this description was obtained from a joint USGS/VWCB investigation that resulted in a 1988 report entitled Hydrogeology and Analysis of the Ground-Water Flow System in the Coastal Plain of Southeastern Virginia. Aquifers are discussed from the lowermost to the uppermost.

Lower Potomac Aquifer

Resting entirely on the Pre-Cretaceous Basement Complex, this aquifer is the lowest and thickest of the region's confined systems. Thickness ranges from near zero at its outcrop area at the Fall Line to 882 feet in the City of Norfolk. Although capable of supplying large quantities of water, it generally lies too deep for most users. Also, high chloride levels in the eastern portion of the aquifer restrict its use as a potable water source.

Middle Potomac Aquifer

The Middle Potomac Aquifer is the second thickest in the SVGMA. It ranges in thickness from zero at its outcrop area at the Fall Line to about 500 feet in the city of Norfolk. This aquifer stores large quantities of water, but, like the Lower Potomac Aquifer, high chloride levels are present in the eastern part of the aquifer. The main users of this aquifer are large industries and municipalities in the central and western portions of the SVGMA. The Middle Potomac Aquifer is overlain by the Upper Potomac Aquifer in the eastern part of the SVGMA and the Aquia Aquifer in western part.

Upper Potomac Aquifer

The Upper Potomac Aquifer is found in the eastern two-thirds of the SVGMA only and, because it does not reach the Fall Line, it is completely confined with no outcrop area. This aquifer thickens from west to east and has been measured to be 280 feet thick in the city of Virginia Beach. Like the two lower Potomac aquifers, this aquifer holds large quantities of water, but is tainted by high concentrations of chloride and fluoride in the eastern part of the region. The Upper Potomac Aquifer is a principal source of water for industrial and municipal users in the central portion of the SVGMA. It is primarily overlain by the Aquia Aquifer, but small areas are overlain by the Virginia Beach Aquifer in the Southeastern portion of the SVGMA and the Chickahominy-Piney Point Aquifer in the northeastern portion.

Virginia Beach Aquifer

The Virginia Beach Aquifer is found in the eastern half of the SVGMA only and, like the Upper Potomac Aquifer, is completely confined with no outcrop area. This aquifer thickens from west to east and is about 110 feet thick in the city of Chesapeake. It is capable of producing moderate to abundant groundwater and mostly supplies industrial and domestic users. The Virginia Beach Aquifer is mostly overlain by the Aquia Aquifer. A small area of the aquifer in the northeastern portion of the SVGMA is overlain by the Chickahominy-Piney Point Aquifer.

Aquia Aquifer

The Aquia Aquifer is found throughout the SVGMA except in the vicinity of the Chesapeake Bay and Atlantic Ocean coast lines. This aquifer is mostly confined, but does crop out along major stream valleys in the western portion of the region. Unlike the other aquifers in the region, the Aquia Aquifer is thickest in the central part of the SVGMA (approximately 65 feet) and thins out to both the east and west. This aquifer provides moderate supplies to small industrial, municipal and domestic users. It is overlain by the Chickahominy-Piney Point Aquifer.

Chickahominy-Piney Point Aquifer

This aquifer is found throughout the SVGMA except in the immediate vicinity of the Fall Line. Like the Aquia Aquifer, it is confined throughout its extent, except where it crops out along major stream valleys in the western portion of the region. This aquifer thickens from east to west and is 160 feet thick in Virginia Beach. Although this aquifer contains moderate to abundant supplies of groundwater, most withdrawals occur in the Williamsburg area, outside the SVGMA. It is overlain by the Yorktown-Eastover Aquifer.

Yorktown-Eastover Aquifer

This aquifer is found throughout the SVGMA except in the middle and upper reaches of stream valleys where it has been removed by erosion. It is unconfined in a large area paralleling the Fall Line. Thickness of this aquifer ranges from near zero in the western part of the SVGMA and along stream valleys to 280 feet in Virginia Beach. The **Yorktown-Eastover Aquifer** is an important water supply for light industrial, commercial and domestic users throughout Southeastern Virginia. It is also an important source of recharge to the underlying confined systems in the western part of the region. In the eastern part of the region, it is overlain by the Columbia Aquifer.

Columbia Aquifer

The **Columbia Aquifer**, also known as the water table aquifer, is the uppermost aquifer and is unconfined throughout its extent. It ranges in thickness from 10 to 80 feet and is present only in the central and eastern portions of the region. The top of the aquifer, or the water table, can vary in depth with precipitation and location from just a few feet to 50 feet below the surface. The Columbia Aquifer serves as a reservoir of recharge to the underlying confined aquifers and is an important source of water for rural and domestic users. It contains mainly freshwater, but may contain salty water near shoreline areas. It is estimated that the portion of this aquifer in the SVGMA contains 6.48 trillion gallons of water.[7] Given the region's average annual precipitation of 44 inches and assuming a recharge rate of 30 percent to 50 percent of annual precipitation, recharge to the Columbia Aquifer is estimated to be between 666 billion and 1.095 trillion gallons per year.[8]

REGIONAL GROUNDWATER USE

USERS OF GROUNDWATER

Under the State Groundwater Act of 1973, as amended, non-exempt groundwater users located within Groundwater Management Areas must obtain Groundwater Withdrawal Permits from the VWCB for withdrawals of greater than an average 10,000 gallons per day. These permits set maximum withdrawal limits for individual wells or well systems. The maximum permitted withdrawals for industrial and municipal wells located in the cities and counties comprising the Southeastern Virginia Planning District can be found in Table 3. As noted, total regional withdrawal allowed under VWCB permits is 160.18 million gallons per day (MGD) (91.12 million MGD for 74 municipal wells and 69.63 MGD for 51 industrial wells). Actual withdrawal is considerably less than what is permitted, however. Many wells are used during emergency situations only, and active wells are generally pumped at rates that are far below those allowed under permit conditions. The USGS estimated that, in 1986, actual groundwater withdrawal from the confined aquifers underlying the Southeastern Virginia Planning District averaged 57.5 MGD.[9] One industry alone, the Union Camp Corporation near the city of Franklin, accounted for 59 percent of this total.[10] Withdrawals from the unconfined Columbia (water table) aquifer were not included in this estimate.

The most recent groundwater withdrawal data by user group for the Planning District are from 1985. At that time, industries accounted for 74.1 percent, public water suppliers accounted for 25.4 percent, irrigation accounted for 0.3 percent, and commercial establishments accounted for 0.2 percent of the average daily regional withdrawal.[11] A breakdown of withdrawals by user group by locality can be found in Table 4.

TRENDS IN LOCAL GROUNDWATER USE

Steadily increasing pumping of groundwater in the deeper confined aquifers (i.e., below the Yorktown-Eastover Aquifer) since the turn of the century in Southeastern Virginia has resulted in significant water level declines, expanding cones of depression around major pumpage centers, and potential contamination by saltwater intrusion. The most significant water level decline is centered on the city of Franklin. Groundwater withdrawals from the Potomac aquifers began in this area in the late 1800s. At that time, these aquifers provided many homes and industries with artesian flowing wells. By the late 1930s, the City of Franklin had begun withdrawing groundwater for its municipal system and a small cone of depression started to form. The potentiometric surface, however, was still at twenty feet above sea level.[12] In 1940, the Union Camp Corporation began withdrawing significant quantities of groundwater to supply its paper mill. By the late 1940s, nearly all artesian wells in the Franklin area had ceased flowing. By 1970, the potentiometric surface at the center of the cone had declined to 165 feet below sea level and the cone of depression had extended to an area of 50 square miles. Since that time,

TABLE 3

PERMITTED INDUSTRIAL AND MUNICIPAL GROUNDWATER WITHDRAWALS IN SOUTHEASTERN VIRGINIA

(Millions of Gallons per Day)

Location of Wells	Industrial	Municipal	Total
Chesapeake	.545	15.757	16.302
Franklin	0	1.720	1.720
Norfolk	1.822	0	1.822
Portsmouth	6.412	0	6.412
Suffolk	1.274	58.339	59.613
Virginia Beach	2.428	0	2.428
Isle of Wight County	48.175	9.570	57.745
Southampton County	8.675	5.460	14.135
TOTAL	**69.331**	**90.846**	**160.177**

Source: Virginia State Water Control Board, Tidewater Regional Office, 1989.

TABLE 4

SOUTHEASTERN VIRGINIA GROUNDWATER WITHDRAWALS BY USE CATEGORY, 1985

(Millions of Gallons Per Day)

Locality	Public	Commercial	Manufacturing	Irrigation	Total
Chesapeake	0.358	0	0.092	0	0.450
Franklin	1.258	0	0	0	1.258
Norfolk	0	0	0.393	0	0.393
Portsmouth	0	0.061	0.509	0	0.570
Suffolk	11.359	0	0.031	0.014	11.404
Virginia Beach	0.135	0.028	0.015	0.133	0.311
Isle of Wight County	0.612	0	35.163	0	35.775
Southampton County	.333	0	4.778	0.007	5.118
TOTAL	14.055	0.089	40.981	0.154	55.279
Percent	25.4%	0.2%	74.1%	0.3%	

Source: State Water Control Board, Tidewater Regional Office, Water Withdrawal Report for 1984-1985, (Virginia Beach, Virginia: SWCB, 1986).

industrial withdrawals have been slightly reduced and water levels have stabilized. As of 1983, deep wells in the vicinity of Franklin accounted for 41 percent of total groundwater withdrawn from the confined aquifers of Virginia's Coastal Plain.[13] The cone of depression that has formed in the Middle Potomac Aquifer around Franklin is illustrated in Figure 6.

As mentioned, in 1986, total withdrawal from the confined aquifers of the Southeastern Virginia Planning District was 57.5 MGD. This represents a nine percent increase from 1983. As indicated in Table 5, 98 percent of the 1983 confined aquifer withdrawals in the Southeastern Virginia Planning District came from the three Potomac Aquifers. Withdrawals from, the Virginia Beach Aquifer are not shown in Table 5 because it was not defined as a separate confined system in 1983. Figure 7 shows trends in estimated annual total and annual aquifer-specific withdrawals between 1891 and 1983 in a 9,200 square mile groundwater flow model area defined for a 1987 USGS study.[14] This model area includes and is significantly larger than the Southeastern Virginia Planning District. However, since most of the withdrawal within the USGS model area occurs within Southeastern Virginia, it can be safely assumed that the trends reflected in Figure 7 accurately reflect the increasing withdrawal of groundwater in the Planning District.

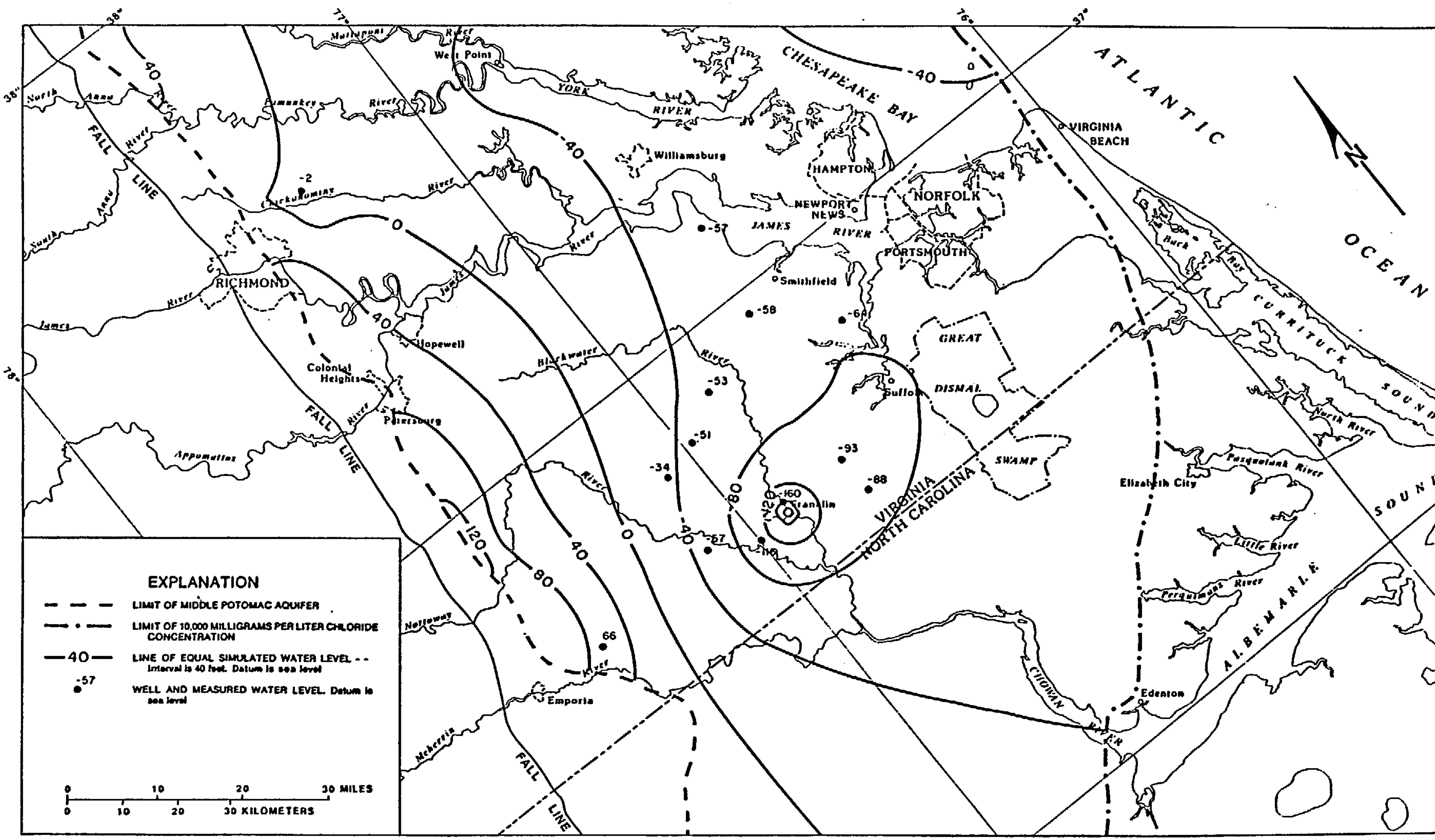
The construction of wells tapping the Columbia and Yorktown-Eastover aquifers has proliferated over the last ten to fifteen years and water levels have dropped significantly as a result. This is in part due to the implementation of mandatory water restrictions in some communities during the droughts of 1977 and 1980. These restrictions encouraged a large number of public water system customers to install wells for domestic, non-consumptive uses (lawn watering, etc.).[15] Many well owners took advantage of new technology and installed well systems that allowed for deeper and larger withdrawals. In addition, increasing energy costs have encouraged the installation of a large number of water-to-air heat pumps which primarily tap the Yorktown-Eastover Aquifer. Also, increased development throughout the region has exacerbated the decline in groundwater levels. Development not only leads to the drilling of more wells, but also increases the amount of impervious surface which causes precipitation to run off rather than infiltrate into the groundwater supply.

In Virginia Beach, there are an estimated 75,000 wells tapping the Columbia and Yorktown-Eastover aquifers, but only 4,000 are used for drinking water. It is estimated that the well users in the Great Neck and Little Neck areas of the city alone may withdraw as much as eleven MGD during the summer for landscape watering. This compares to only an estimated 0.8 to 1.5 MGD for heat pumps and drinking water.[16]

As a result of increased usage of the Columbia and Yorktown-Eastover aquifers, heavy pumping during times of drought has lowered the water level of the Yorktown-Eastover Aquifer to a depth below the intake capability of many local well pumps. During the drought of 1985, over 200 wells went dry in the Great Neck and Little Neck areas.[17] Due to water level declines, new wells are typically drilled to a depth of 40 to 150 feet, whereas depths of ten to fifteen feet previously sufficed.[18]

FIGURE 6

SIMULATED AND MEASURED WATER LEVELS IN THE MIDDLE POTOMAC AQUIFER, 1983



Source: USGS, <u>Hydrogeology and Analysis of the Groundwater - Flow System in the Coastal Plain Southeastern Virginia</u>, (Richmond, Virginia: USGS, 1988), p. 91.

TABLE 5

WITHDRAWALS BY LOCALITY FROM THE CONFINED AQUIFERS OF SOUTHEASTERN VIRGINIA, 1983

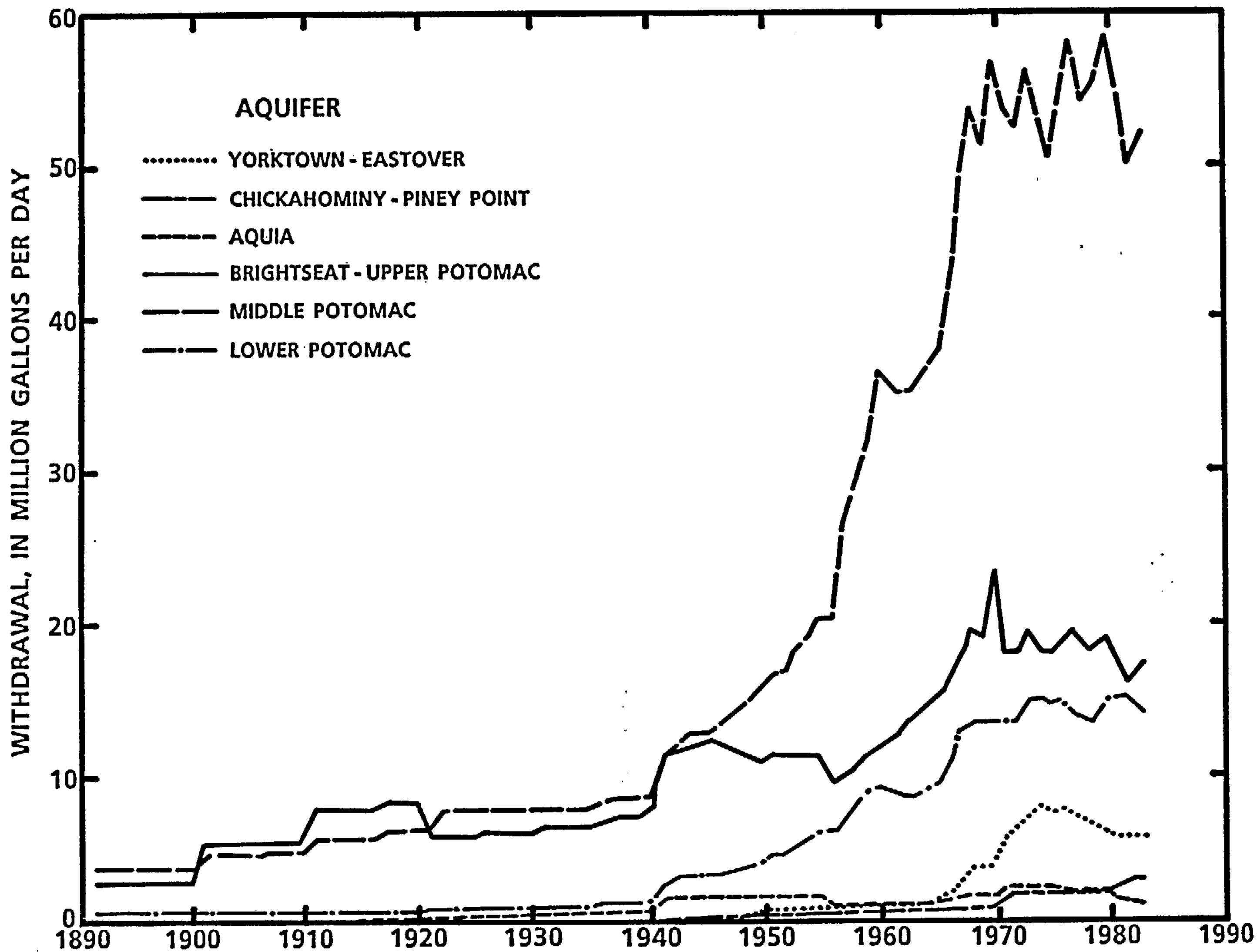
(Millions of Gallons per Day)

Locality	Lower Potomac	Middle Potomac	Upper Potomac	Aquia	Chickahominy-Piney Point	Yorktown-Eastover	Total
Chesapeake	0	0	.026	.015	0	.420	.461
Franklin	0	.460	0	0	0	0	.460
Norfolk	0	0	.206	0	0	.049	.255
Portsmouth	0	0	.455	.136	0	.166	.757
Suffolk	.109	6.173	1.748	0	0	.089	8.119
Virginia Beach	0	0	0	0	0	.166	.166
Isle of Wight County	9.713	23.791	3.295	.086	0	0	36.885
Southampton County	.390	5.460	.031	0	0	0	5.881
TOTAL	10.212	35.884	5.761	.237	0	.890	52.984
Percent	19.3%	67.7%	10.9%	0.4%	0%	1.7%	100%

Source: U.S. Geological Survey, Ground-Water Withdrawals from the Confined Aquifers in the Coastal Plain of Virginia, 1891-1983, (Richmond, Virginia: USGS, 1987), p.14.

FIGURE 7

TRENDS IN AQUIFER - SPECIFIC WITHDRAWALS, 1891-1983



Source: USGS, Groundwater Withdrawals from the Confined Aquifers in the Coastal Plain of Virginia, 1891-1983, (Richmond, Virginia: USGS, 1987), p.13.

GOVERNMENT'S ROLE IN PROTECTING GROUNDWATER

FEDERAL GOVERNMENT

Before the mid-1970s, the federal government played only a limited role in protecting groundwater. Federal environmental legislation in place at that time dealt primarily with surface water pollution. The limited role of the federal government in protecting groundwater was due, in part, to a lack of information regarding the nature and extent of groundwater contamination problems, but also to a basic philosophy that protection efforts were the responsibility of state and local governments. In the mid to late 1970s, however, groundwater contamination problems became better understood and pressure was exerted on the federal government to take a more active role in protection efforts.

Direct federal involvement in groundwater protection was first evident in the enactment of the Safe Drinking Water Act (SDWA) of 1974. This Act was passed to "assure that water supply systems serving the public meet minimum national standards for the protection of public health." To meet this goal, the Act authorizes the U.S. Environmental Protection Agency to (1) develop and enforce drinking water standards for contaminants, (2) establish a program to regulate underground injection activities, and (3) designate sole source aquifers to protect recharge areas. The regulations implementing these provisions are designed to encourage states to initiate groundwater protection programs that reflect local needs and hydrogeologic settings. Amendments to the SDWA in 1986 created two additional groundwater protection programs that are implemented by the states. The first is the Wellhead Protection Program which requires states to develop programs, which involve local governments, to protect the wellhead areas of public water supply wells. The second program provides grants for critical aquifer protection demonstration programs in selected communities.

In addition to the SDWA, a number of other federal statutes were enacted in the mid to late 1970s that direct the EPA and other federal agencies to address specific environmental threats that may contaminate groundwater. As with the SDWA, the primary responsibility for implementing most of these statutes lies with the states. These statutes include the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund"), the Surface Mining Control and Reclamation Act, the Uranium Mill Tailings Radiation Control Act, the Hazardous Materials Transportation Act, the Hazardous Liquid Pipeline Safety Act, the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), and the Toxic Substances Control Act. Other federal statutes take a broader approach to a variety of environmental protection issues, but contain provisions that are relevant to groundwater protection. These include the Water Quality Act, the Coastal Zone Management Act and the National Environmental Policy Act. Appendix B contains a brief summary of those federal statutes which pertain to groundwater protection and which are applicable in Southeastern Virginia.

As indicated above, groundwater protection is addressed through a number of federal programs that are designed for different purposes. There is no comprehensive federal law, like the Clean Air Act or the Water Quality Act, that specifically addresses groundwater management. As a result, it became apparent in the early 1980s that there were considerable gaps in the federal approach to groundwater protection. To close these gaps, the EPA adopted a Groundwater Protection Strategy in 1984. This Strategy is designed primarily to coordinate federal regulatory programs and to strengthen state programs. In this strategy, the EPA reaffirms that states have the primary responsibility in developing their own groundwater protection programs with planning assistance and limited funding assistance from the federal government. The EPA Groundwater Protection Strategy relies on various authorities contained in the above-noted statutes and consists of the following major components:

- Short-term buildup of institutions at the state level through technical assistance and grants;

- Assessment of problems that may stem from sources of contamination not addressed in existing legislation;

- Issuance of guidelines for EPA decisions affecting groundwater protection and cleanup. These guidelines are based on a three-tier groundwater classification system; and

- Strengthening EPA's organization for groundwater management and EPA's cooperation with federal and state agencies.

STATE GOVERNMENT

As mentioned, there is no comprehensive federal statute which requires states to adopt laws and develop programs that are specifically related to groundwater protection. Approaches to protecting groundwater vary significantly from state to state. In Virginia, a legal mandate to protect groundwater lies in Article XI, Section 1 of the Virginia Constitution which declares that it is a policy of the Commonwealth "to protect its atmosphere, lands and waters from pollution, impairment, or destruction, for the benefit, enjoyment and general welfare of the people of the Commonwealth." The State Water Control Law (SWCL) was enacted in 1946 to carry out this mandate as it pertains to the protection of "state waters." Under the SWCL, the definition of state waters includes both surface waters and groundwater. The VWCB was created to enforce and administer the SWCL.

The SWCL includes what is called an "anti-degradation policy." This policy provides for the protection of existing high quality waters, and for the restoration of all other waters to a level of quality that will permit all reasonable uses and support aquatic life. The anti-degradation policy is interpreted and refined by water quality standards developed and adopted by the VWCB. The current antidegradation policy and groundwater quality standards can be founded in Appendix C. In 1988, an advisory group was formed which reviewed and recommended refinements to the anti-degradation policy. The VWCB staff has reviewed the groups recommendations and plans to propose a revised policy to its Board in March 1990. In addition, the existing groundwater quality standards are currently under review and may undergo revisions in the near future.

In viewing the anti-degradation policy and the VWCB's water quality standards together, the Virginia Groundwater Protection Steering Committee has arrived at the following conclusions regarding the State's ability to protect groundwater.[19]

- There is no right to degrade the groundwater of Virginia from its natural quality.

- No groundwater source is pre-classified to allow degradation by human activity.

- Those responsible for groundwater pollution that has occurred or might occur can be required to restore the water to its natural condition.

- Groundwater protection activities must take social and economic consequences into account.

Although the VWCB has primary responsibility for groundwater protection in Virginia, a number of State agencies administer a variety of federal and State mandated programs that either directly or indirectly address groundwater quality management. Table 6 contains a listing of State agencies and their programs which deal in some way with groundwater protection. These programs are described in detail in the Virginia Groundwater Management Handbook which was prepared by the GWPSC in 1988.

With the exception of a few formal and informal agreements between the VWCB and other State agencies, there has not, until recently, been an attempt to develop a comprehensive, inter-agency strategy to implement the State's groundwater protection authority. In 1973, the Groundwater Act was passed to provide for the designation of Groundwater Management Areas where groundwater supplies are overdrawn or polluted, and to establish a permitting system for withdrawals in such areas. The primary focus of this legislation, however, was groundwater quantity, not quality.

TABLE 6

GROUNDWATER PROTECTION RESPONSIBILITIES OF STATE AGENCIES

Virginia Water Control Board (VWCB)

- statewide groundwater resource management
- regulation of non-hazardous waste pits, ponds, and lagoons; land application of non-hazardous waste; commercial and industrial drainfield systems; underground storage tanks; animal waste lagoons
- groundwater monitoring, data collection, and management
- groundwater modeling
- municipal wastewater treatment (joint program with VDH)
- municipal water treatment residue disposal

Virginia Department of Waste Management (DWM)

- solid waste management (landfill permits)
- hazardous waste management (RCRA permits; superfund program)
- radioactive waste management

Virginia Department of Health (VDH)

- on-site sewage disposal permits (septic systems)
- public water supply
- water well construction standards
- municipal wastewater treatment (joint program with VWCB)

Virginia Department of Conservation and Recreation (VDCR), Division of Soil and Water Conservation (DSWC)

- agricultural non-point source pollution control (fertilizers and pesticides, animal waste management)
- urban nonpoint source pollution control (stormwater management)

Virginia Cooperative Extension Service (VCES)

- pollution education programs
- agricultural groundwater use data collection
- soil nutrient testing service
- agricultural technical assistance

Virginia Department of Agriculture and Consumer Services (VDACS)

- regulation of pesticide and herbicide applicators
- integrated pest management

Virginia Department of Mines, Minerals, and Energy (DMME)

- geologic mapping, drill cutting, and core analysis
- mine regulation
- oil and gas well regulation

Virginia Department of Emergency Services

- assistance in responding to hazardous materials spills

Virginia Department of Housing and Community Development (VDHCR)

- land use planning assistance

Virginia Council on the Environment (COE)

- inter-agency environment coordination

Source: Virginia Groundwater Protection Steering Committee, A Groundwater Protection Strategy for Virginia, Richmond, Virginia: VWCB, 1988, p. 8.

As mentioned at the beginning of this Handbook, the Virginia Groundwater Protection Steering Committee was formed in 1985. Impetus for formation of the GWPSC came from the EPA which, through its Groundwater Protection Strategy, awarded a grant to the State for the development of its own groundwater protection strategy. This federal assistance coincided with a growing recognition by the State that it must improve both state and local groundwater protection capabilities. The GWPSC is chaired by the VWCB and is comprised of representatives from a number of State agencies whose programs affect groundwater quality.[20] The GWPSC's stated mission was to assess current problems, identify program needs and set priorities for new groundwater protection programs. In 1986, the GWPSC began a year-long planning effort which culminated in the 1987 publication of <u>A Groundwater Protection Strategy for Virginia</u>. This document identifies the greatest threats to the quality of Virginia's groundwater and presents a number of specific recommendations to improve groundwater quality protection throughout the state. The Strategy emphasized the importance of cooperation among State agencies as well as coordination among the different levels of government, and specifically called for more involvement by local governments.

The efforts of the GWPSC were reinforced by the creation, in 1986, of the Secretariat of Natural Resources. This Cabinet-level office groups together under one authority those State agencies involved in a diversity of environmental protection activities. The Secretariat is empowered with strong management, planning and budgeting authority, and is specifically mandated to ensure interagency coordination in dealing with the full range of environmental issues, including groundwater protection.

Since publication of <u>A Groundwater Protection Strategy for Virginia</u>, a number of the proposed recommendations have been implemented. In addition, several State initiatives that are consistent with but not specifically mentioned in the proposed recommendations have been undertaken in response to federal mandates. A listing of recent State initiatives undertaken to promote groundwater protection are shown in Table 7.[21]

LOCAL GOVERNMENT

Decisions made by local governments have the greatest potential to impact groundwater quality. Ironically, Virginia localities have been least involved in groundwater protection. One reason for this lack of involvement is that the ability of Virginia localities to address groundwater quality management has been limited by the State's reliance on the Dillon Rule. Under the Dillon Rule, localities can assume only those powers that are expressly given to them by the State legislature. Virginia localities do, however, possess certain powers that can be used to promote environmental protection. These include the authority to construct sewers, to implement water conservation programs, to prevent the pollution of water and injury to waterworks and, most importantly with regard to groundwater protection, to adopt comprehensive plans, zoning ordinances and subdivision ordinances.[22] As previously mentioned, the 1988 Virginia General Assembly legitimized local

TABLE 7

RECENT STATE INITIATIVES PROMOTING GROUNDWATER PROTECTION

Water Control Board

- The development of the Virginia Pollutant Abatement permit program which provides greater regulatory control over sources of pollutants which are not point source discharges to surface waters.
- The development of a State underground storage tank regulatory program.
- A study to determine how groundwater data can better be collected and managed by State agencies.
- A training program through which local planners can evaluate the relative groundwater pollution potential of different land areas by using the DRASTIC model.
- The development of technical groundwater protection training programs for State agency personnel.
- A review of the State's anti-degradation policy.
- The preparation of the Virginia Groundwater Management Handbook.

Department of Waste Management

- The development of new landfill management regulations which include groundwater protection measures.
- Development of a program to reduce waste volume and toxicity when a product is manufactured.
- The development of solid waste planning and recycling programs.

Department of Health

- The development of draft regulations which establish construction standards for private wells.
- A research program designed to investigate alternative septic system designs.
- The establishment of an advisory committee to review the State's Sewage Handling and Disposal Regulations.

Chesapeake Bay Local Assistance Board

- The development of performance criteria for septic systems located in Chesapeake Bay Preservation Areas designated under the Chesapeake Bay Preservation Act.

TABLE 7 (Continued)

RECENT STATE INITIATIVES PROMOTING GROUNDWATER PROTECTION

Department of Conservation and Recreation

- The development and EPA-approval of the Virginia Nonpoint Source Management Program.

Department of Agriculture and Consumer Services

- Staffs the Virginia Pesticide Control Board and implements the 1989 Virginia Pesticide Control Act.

- Development of a pilot "clean day" project through which commercial and private applicators can dispose of unwanted or banned pesticides.

Council on the Environment

- Preparation of a State groundwater protection handbook.

Virginia Cooperative Extension Service

- The sponsoring of regional seminars and other educational programs on groundwater protection.

Other

- The amendment of existing planning enabling legislation to provide more power to localities to consider groundwater protection in their land use planning activities.

Source: Virginia Groundwater Protection Steering Committee, 1988 and 1989.

government authority to address groundwater protection in local land use regulations by adding groundwater to the list of items that may be considered in preparing a comprehensive plan and that must be considered in preparing a zoning ordinance.

Another reason why local governments have not been more involved in groundwater quality management is that certain powers that could be used locally to protect groundwater have been preempted by either State or federal statute and, therefore, cannot be exercised by localities. For instance, the Virginia Department of Health regulates septic systems and well construction standards, the Virginia Department of Waste Management regulates solid waste disposal, and the VWCB regulates the discharge of pollutants into State waters.

A Groundwater Protection Strategy for Virginia cites two additional reasons for local inactivity in groundwater protection. These are a lack of awareness and a lack of information. Local governments are becoming more aware of the potential threats to local groundwater supplies and the importance of taking preventive measures to head off potentially expensive and environmentally catastrophic groundwater contamination incidents. An improved information base is also necessary so that local governments can make informed decisions when taking local actions that may impact groundwater quality.

Local government may be taking an increasingly active role in the regulation of activities that may impact groundwater quality. As previously mentioned, one of the 1986 amendments to the Safe Drinking Water Act requires states to develop programs which involve local governments in establishing wellhead protection areas around community wells. Within these areas, control measures will be required to protect wells from contamination. These measures will be implemented by local governments with guidance from the states. Another 1986 amendment to the SDWA provides funding for demonstration projects in selected communities. This legislation allows localities to bypass state government and apply directly to EPA for funding. At the state level, new regulations require each locality to develop a comprehensive solid waste management plan and incorprate more stringent standards in solid waste disposal facility construction and operation. Localities are also required to regulate land use near solid waste management facilities so as to insure local compatibility with such a facility.

GROUNDWATER QUALITY PROBLEM AREAS IN SOUTHEASTERN VIRGINIA

This chapter describes known groundwater contamination problems in Southeastern Virginian, and identifies areas that may be particularly susceptible to groundwater contamination.

NATURALLY OCCURRING GROUNDWATER QUALITY

Before discussing the incidence of human-induced contamination of Southeastern Virginia's groundwater supplies, it is important to note that there is wide variation in the natural quality of the region's groundwater. Naturally occurring chemical constituents may make groundwater unsuitable for some uses and may exceed concentrations set by drinking water standards.

With several exceptions, the overall natural quality of the region's groundwater is high. In the eastern portion of the region, however, the Potomac aquifers have high chloride levels due to an eastward thickening wedge of brackish and saline water. The top of this wedge can be detected at about 100 feet below sea level in the extreme eastern portions of the region. It gradually deepens to the west, but its western extent has not been precisely defined. Isolated pockets of saline water may also be found resting in the basement complex as far west as the Fall Line.[23] In the shallower aquifers, chloride levels are generally within acceptable limits except in the immediate vicinity of tidal waters. Unless expensive treatment processes are employed, high chloride levels may impart an objectionable taste to water. Also, high levels of chloride often indicate the presence of high sodium concentrations. High sodium levels may be harmful to people with high blood pressure. As will be discussed later, excessive pumping in some areas of Southeastern Virginia may be responsible for a rise in chloride levels in existing wells.

Other naturally occurring groundwater quality problems that are common to Southeastern Virginia include high fluoride and sodium levels in the deeper aquifers, and high iron levels and high acidity in the shallower aquifers. Although moderate levels of fluoride strengthen tooth enamel and prevent cavities, excessively high concentrations may damage teeth and bones. High iron concentrations are not dangerous, but may stain appliances, plumbing fixtures, clothes, sidewalks and so forth, and may give food and beverages an unpleasant taste. Highly acidic water, a problem generally found in withdrawals from the Columbia aquifer, may corrode well casings, plumbing fixtures or other metal objects. Corrosion of copper plumbing in homes may cause liver damage.

HUMAN-INDUCED GROUNDWATER QUALITY PROBLEMS

Large-scale, human-induced contamination of Southeastern Virginia's aquifers is not a problem. However, the region has experienced a number of localized groundwater contamination incidents in which finite areas near specific sources of pollutants have been affected. Through information gathered from existing literature, VWCB records, and interviews with local planning, public utilities and health officials, the following have been identified as the greatest threats to groundwater in Southeastern Virginia:

- Septic systems
- Underground storage tanks
- Spills and improper disposal of hazardous materials
- Surface waste impoundments
- Landfills
- Pesticide and fertilizer applications
- Saltwater encroachment

This list closely resembles the statewide source priority list established by the Virginia Groundwater Protection Steering Committee. Although other potential sources of groundwater pollution exist in Southeastern Virginia, there is little evidence that significant contamination from these sources has occurred.

The following section discusses known and suspected groundwater contamination problems in Southeastern Virginia attributable to the sources listed above. There is widespread belief among officials involved in local groundwater management that contamination is more prevalent than existing information would indicate. It is quite probable that a significant amount of groundwater pollution, from all of the sources identified, has gone undiscovered due to a lack of comprehensive monitoring programs and the localized nature of most contamination incidents. One reason for this is that, in the urban areas of the region, groundwater contamination has not been a high priority issue since nearly all residents are served by municipal water systems. It is also important to note that, as the region continues to experience a rapid rate of development, the potential for groundwater contamination incidents attributable to the identified sources will increase.

Septic Systems

A 1988 study by the Virginia Water Project estimated that over 50,000 housing units in the Southeastern Virginia Planning District rely on on-site sewage systems.[24] The study determined that approximately 45,000 of these units use septic systems, while the remainder use other on-site practices, usually outhouses. In addition to single household disposal systems, the region has a number of mass drainfield systems which serve businesses, clusters of houses, schools, and so forth.

On-site sewage systems are the largest contributors of wastewater to the ground, and failing or inadequate systems are generally considered to be a common source of groundwater contamination. Problems arise when systems are improperly designed, constructed or maintained, or are located too close to the water table or in soils which do not adequately percolate. The Virginia Water Project estimates that nearly 4,000 housing units in Southeastern Virginia have systems which are improperly constructed and/or located. The Virginia Water Project notes that this is a conservative estimate that mostly reflects the problem of septage ponding on the ground surface and not the discharging of raw septage below the water table.[25]

Wastewater from septic systems contains a variety of contaminants including nitrates, bacteria, viruses, and a variety of organic and inorganic chemicals used in common household products. A large majority of the on-site sewage systems are found in areas which are dependent on private wells for drinking water. Consequently, there is a possibility that on-site sewage systems will contaminate improperly sited or inadequately sealed wells. The Virginia Water Project estimates that there are more than 14,000 inadequately constructed, drilled or dug wells in the Southeastern Virginia Planning District.

The extent to which on-site sewage systems contaminate groundwater in Southeastern Virginia is unclear. Only a few cases of domestic well contamination by septic systems have been documented. However, there have been a number of cases where high bacteria or nitrate levels have been found in wells. Verification of the source of these contaminants was not possible. For example, due to excessive levels of nitrates found in the domestic wells of a rural neighborhood in Virginia Beach, the City advised local children and senior citizens not to drink well water. The source of these nitrates could not be determined, though septic systems were suspected. The City remedied this problem by extending public water lines to the neighborhood.[26]

Underground Storage Tanks

The Resource Conservation and Recovery Act was amended in 1984 to require the regulation of certain underground storage tanks (USTs). Under these regulations, owners of non-exempt USTs that were in the ground on or after May 8, 1986 must be registered with the VWCB. As shown in Table 8, by August 1988, the VWCB had been notified of the existence of 6,370 non-exempt USTs at 2,326 sites in Southeastern Virginia. VWCB officials have indicated that there may be twice that number of non-exempt USTs that have not yet been registered.

VWCB registration is not required for USTs that are exempt from RCRA regulations. These include heating oil tanks of less than 5,000 gallons and any farm and residential USTs storing less than 1,110 gallons. There are no reliable estimates on the number of such tanks in Southeastern Virginia. VWCB officials believe that residential heating oil tanks may be a significant threat to groundwater.[27]

TABLE 8

REGISTERED UNDERGROUND STORAGE TANKS IN SOUTHEASTERN VIRGINIA AS OF AUGUST 1988

	NO. OF SITES	NO. OF USTS	SUBSTANCE STORED (No. of USTs)					AGE OF USTs		ABANDONED[2]
			Petroleum Product[1]	Other Haz. Material	Water	Unknown	Empty	More than 13 years	Unknown	
Chesapeake	371	959	844	16	9	19	71	296	92	90
Franklin	41	128	107	0	0	1	20	49	12	15
Norfolk	671	1,895	1,664	52	30	53	96	684	258	222
Portsmouth	264	713	601	9	16	24	63	294	104	82
Suffolk	194	573	518	5	1	7	42	226	91	54
Virginia Beach	540	1,428	1,335	20	6	23	44	411	165	163
Isle of Wight County	107	314	259	2	0	3	50	148	30	27
Southampton County	138	360	317	0	0	1	42	160	37	19
TOTAL	**2,326**	**6,370**	**5,645**	**104**	**62**	**131**	**428**	**2,268**	**789**	**672**

[1]Includes gasoline, diesel fuel, kerosene, used oil, heating oil, hydraulic fluid, jet fuel and so forth.

[2]Most abandoned registered tanks are known to be empty.

Source: Virginia State Water Control Board, 1988.

Of the substances stored in the region's USTs, petroleum products pose the greatest threat to groundwater. VWCB data indicate that approximately 88 percent of the region's registered USTs contain some type of petroleum product. Such products can be extremely pervasive in an aquifer. It is estimated that one fifth of a gallon of gasoline can contaminate one million gallons of groundwater at a level of five parts per billion.[29] Also, small amounts of petroleum products can affect the taste and potability of groundwater and can be extremely hazardous to human health and safety. For example, benzene and toluene, two chemicals found in gasoline, are considered priority pollutants by the EPA and are toxic and carcinogenic at low concentrations.

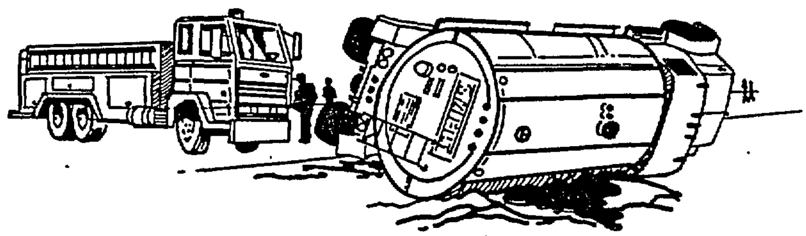
Hazardous materials other than petroleum-based substances are found in only two percent of the region's registered USTs. These materials, which mostly include pesticides and solvents, generally pose less of a threat to groundwater because relatively small quantities are stored in fewer tanks. Moreover, tanks containing these substances are generally newer with better leak protection than tanks storing petroleum products.

The extent to which the region's USTs are leaking and contaminating groundwater is unknown. VWCB staff estimates that between five percent and 30 percent of all USTs are leaking.[30] Leakage is strongly correlated with tank age. An official from a company that services and replaces USTs estimates that between 50 percent and 70 percent of all USTS installed before 1965 have some corrosion.[28] VWCB staff estimates that, on average, tanks begin leaking after thirteen years of use.[31] As indicated by Table 8, nearly 36 percent of the region's registered USTs were thirteen years or older at the time of registration. An additional twelve percent of the tanks were of unknown age. It is assumed that most tanks of unknown age are older since records are non-existent. VWCB data files indicate that there is a large number of USTs throughout the region that are 30 to 50 years old, contain large quantities of petroleum products, and are not internally or externally protected against leakage. This situation is particularly common at military facilities. It is likely that a significant amount of leakage and groundwater contamination occurs from these tanks.

Pollution complaints reported to the VWCB between July 1986 and August 1989 include 126 pollution incidents involving groundwater contamination in Southeastern Virginia. In 82 of these incidents, contamination was determined or suspected to be a result of leaking or abandoned USTs containing petroleum products. Most of these incidents were discovered by UST owners who were in the process of upgrading their tanks to meet new requirements contained in recent EPA regulations. These regulations were developed in 1988 (and adopted by the VWCB with some minor modifications in 1989) to implement the 1984 RCRA UST amendments. Under these regulations, all owners of existing, non-exempt USTs must test and protect their tanks, identify and correct leaks, and clean up spills and releases. The 1984 RCRA amendments specify that all regulated USTs must be upgraded to meet the new regulations by 1998. VWCB staff expects that, as more tank owners comply with these regulations, substantially more incidents of UST contamination will be discovered.

Spills and Improper Disposal of Hazardous Materials

Potential groundwater contamination problems in this category include any incidents where hazardous materials are either accidently spilled or intentionally dumped on the ground. Major incidents of this type may occur during transport, or at fixed industrial or commercial facilities. Smaller but cumulatively significant incidents may occur illicitly at private residences or in remote areas.



An estimated eighteen percent of the trucks on Virginia's highways carry hazardous materials.[32] In addition, significant quantities of hazardous materials are transported by rail. Groundwater contamination rarely occurs as a result of transport-related spills, however. This is because such spills are usually more visible, present an immediate danger and, therefore, invoke prompt emergency responses.

Although spills of hazardous materials sometimes occur during transportation, they are generally more common and more damaging at fixed commercial and industrial facilities. At these facilities, emergency response may not be as quick since spills may go unnoticed and may even be intentional. Also, spills at fixed facilities may be small but reoccurring, such as the continual overfilling of a storage tank. In these cases, individual incidents may appear insignificant, but the cumulative effects of numerous spills over time could result in considerable contamination. VWCB files indicate that, of the groundwater contamination incidents occurring in Southeastern Virginia between July 1986 and August 1989, fourteen were at least partially attributed to spills or improper ground disposal at commercial and industrial facilities. All but one of these incidents involved petroleum products. In addition, three of the region's four Superfund cleanup efforts involve industrial sites where the long-term dumping of hazardous materials on the ground has resulted in the contamination of soil and groundwater.[33] The State also has a separate hazardous waste cleanup program which deals with those sites which either require emergency remediation or are not eligible for the Superfund program. Six of the region's seven State cleanup sites involve soil and/or groundwater contamination from hazardous material spills or dumping.

It is likely that there are many more abandoned or existing industrial sites where the spilling or dumping of hazardous materials has led to groundwater contamination. Sixty-two sites in Southeastern Virginia are currently being studied by the Virginia Department of Waste Management and the EPA to determine either their eligibility for inclusion on the Superfund National Priorities List or their potential as State Cleanup sites. At many of these sites, soil and/or groundwater contamination from hazardous material spills or dumping is suspected.

A CERCLA (Superfund) site discovery project for the Elizabeth River Basin was completed in 1988 by the NUS Corporation under contract to the EPA. This project, which is the first phase of a long-term effort to refine the Superfund National Priorities List, resulted in an inventory of 377 potential hazardous waste sites considered worthy of further investigation.[34] This inventory was prepared through an analysis of fifty years of aerial photography. A large number of the inventoried sites were found to have ground stains or discolored soils which may be an indication of past spilling or dumping of hazardous materials.

There are no reliable data on the incidence of illicit, off-site dumping of hazardous waste by businesses and industries. Although RCRA provides for the strict regulation of hazardous wastes "from cradle to grave", the practice of illegal dumping continues. Press reports indicate that there have been several such incidents in Southeastern Virginia in recent years. It is likely that many more incidents have gone undetected. When discovered and responded to quickly, groundwater contamination from illicit hazardous material releases is usually avoided. Over time, however, undetected releases are likely to have significant localized impacts on groundwater.

Illegal dumping of hazardous wastes by homeowners is also considered to be a significant threat to groundwater in the more developed portions of the region. Commonly disposed of household hazardous wastes include drain cleaners, paint thinners, household cleaners, solvents, motor oil, battery acids, swimming pool chemicals, unwanted fuels and pesticides. Soil and/or groundwater contamination may occur by dumping these materials on the ground or by flushing them through septic systems. There is little information on the amount of household hazardous waste that is disposed of properly or improperly since disposal of such substances is not governed by federal or State regulations. It is estimated that the average household contains between three and ten gallons of materials that are potentially hazardous to human health or the environment.[35] Although quantities improperly disposed of by individual households may be small, the cumulative impacts of disposal by entire communities could be significant. Used motor oil is one of the more commonly disposed ofhousehold hazardous wastes. The

Virginia Division of Mines, Minerals and Energy estimates that Virginians dump 4.4 million gallons of used motor oil into the environment per year. It is estimated that one quart of oil can contaminate up to 250,000 gallons of surface water.[36] Although this finding is not directly relevant to groundwater, it is an indication of the pervasiveness of oil when mixed with either surface water or groundwater.

Surface Waste Impoundments

Surface waste impoundments are used by industries, agricultural operations and municipalities for the retention, treatment and/or disposal of hazardous and non-hazardous liquid wastes. In 1985, there were 430 industrial, 1,200 animal waste and relatively few municipal surface impoundments in Virginia.[37] The number of these impoundments that are located in Southeastern Virginia has not been determined. However, given large number of industries and animal feedlots in the Southeastern Virginia, it is likely that a high proportion of the state's surface impoundments are located in this region.

Leaking surface impoundments can easily contaminate groundwater. This is particularly true in Southeastern Virginia where the water table is usually found close to the surface. Until recently, most surface impoundments in Virginia have been constructed without, or with inadequate, liners. The VWCB now regulates the construction and operation of surface impoundments under either the NPDES or the Virginia Pollution Abatement (VPA) permit programs. In accordance with the 1984 RCRA amendments, the VWCB requires liners for all new surface impoundments containing wastes regulated under RCRA. The VWCB may require liners for impoundments containing RCRA-exempt wastes as a permit condition where groundwater is threatened. In situations where there is a high potential for groundwater contamination, the VWCB may also require a liner as a condition for NPDES or VPA permit renewal.

In spite of the current regulations requiring liners, there are many unlined surface impoundments throughout Southeastern Virginia that were constructed before the current requirements were implemented. VWCB records indicate that there were two groundwater contamination incidents involving leaking surface impoundments between July 1986 and August 1989. VWCB staff believes that there is a high likelihood that many more impoundments are causing undetected, localized groundwater contamination.

Of the 377 potential hazardous waste sites identified during the Elizabeth River Basin CERCLA site discovery project, 70 sites (57 private and 13 federal) were identified as existing or abandoned industrial waste impoundments. It is probable that many of the privately-owned sites are permitted and conform with RCRA regulations. Future investigations will most likely reveal that some of the unregulated industrial waste impoundment sites identified during this project have contributed to local groundwater contamination.

Landfills

A **landfill** is land that is set aside, and usually excavated, for the disposal of solid waste. In the past, landfills were either sanitary (i.e., where refuse is compacted and frequently covered with soil) or were uncovered, open dumps. During the last two decades there has been a growing awareness of the hazardous substances disposed of in landfills and the potential for these substances to leach through landfills and contaminate groundwater. In response to this concern, RCRA required the classification and closure of open dumps. RCRA also required entities generating significant quantities of hazardous wastes to manage and track these wastes and to dispose of them in permitted hazardous waste facilities. Due to these regulations, large quantities of hazardous wastes have been directed away from landfills. However, there are still significant quantities of hazardous substances found in common municipal waste which can be leached out of a landfill and cause significant groundwater contamination. The 1984 amendments to RCRA required the EPA to provide states with guidelines for permitting solid waste landfills. The Virginia Department of Waste Management adopted these guidelines and promulgated new solid waste regulations which took effect in January, 1989. These regulations promote groundwater protection by guiding proper siting, design, management and closure of landfills.

Implementation of Virginia's new permitting regulations is just beginning. Some well maintained and operated landfills already meet the new regulations, but other landfills fall well short of compliance. In Southeastern Virginia, there are four public and 17 private landfills. In 1988, the public waste system alone received 1.1 million tons of refuse. Groundwater contamination has been either documented or suspected at several of these sites. In addition to these operating landfills, there are many abandoned or closed landfill sites which are suspected of causing groundwater contamination. One of the region's four Superfund sites is a closed public landfill in Suffolk located in a former swamp. This site has contaminated monitoring wells and at least one off- site well, and is suspected of contaminating a drainage ditch in the nearby Great Dismal Swamp National Wildlife Refuge.

Groundwater contamination has also occurred at an abandoned military landfill that is being cleaned up under the State's hazardous waste cleanup program. In addition, of the 377 potential hazardous waste sites identified during the Elizabeth River Basin CERCLA site discovery project, 33 were identified as existing or abandoned landfills. It is possible that a number of these sites have caused local groundwater contamination.

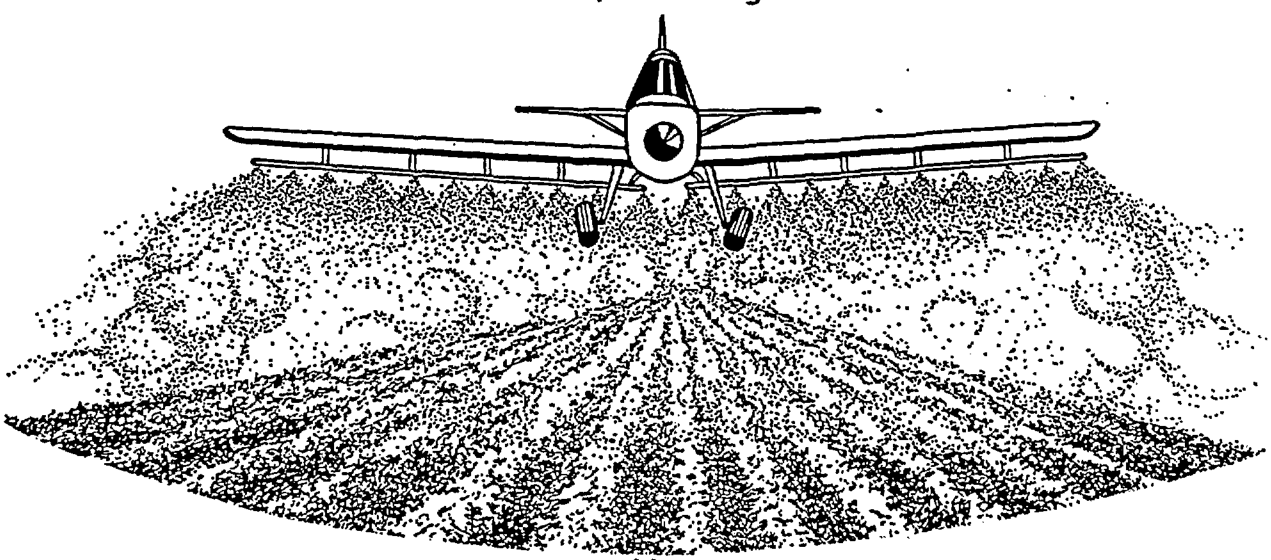
Pesticide and Fertilizer Applications

Pesticides and fertilizers are used extensively throughout the region in agriculture, silviculture, urban park management and in residential lawn and garden care. The ability of a pesticide or fertilizer to contaminate groundwater depends on a number of interdependent factors including application rate; decomposition rate; water solubility of the chemical; degree of crop uptake; geologic characteristics of the soil, unsaturated zone and the aquifer; and the depth to the water table. Often, significant contamination occurs not from misapplication, but from long term accumulation from years of repeated applications.

The total amount of pesticides used in Southeastern Virginia is unknown. At present, there are no State reporting requirements for pesticide sales or use. This may change, however, under the 1989 Virginia Pesticide Control Act which requires the newly created State Pesticide Control Board to promulgate regulations which would, among other things, strengthen reporting requirements for vendors, and commercial and private applicators. In addition, the Virginia Department of Agriculture and Consumer Services intends to conduct statewide pesticide usage surveys in the near future.

Although pesticides have been found to cause cancer, liver, kidney and central nervous system damage, and eye and skin irritation, there is little evidence linking groundwater contaminated by pesticides to human health problems. Most experts agree, however, that, though inadequately documented, the potential for negative health effects does exist. There is also the potential for water quality degradation resulting from the migration of pesticide-contaminated groundwater into surface waters.

Although relatively major cases of groundwater contamination by pesticides have occurred in Virginia, there have been few reported cases in this region. Of the groundwater contamination incidents reported to the VWCB between 1986 and 1989, only two involved pesticides. It is possible, however, that other pesticide contamination incidents have occurred, but have gone undetected.



Nitrogen in the form of nitrate is the fertilizer most commonly responsible for groundwater contamination. This is because nitrogen is highly stable and water soluble and therefore leaches easily through the soil. Other commonly used fertilizers, phosphorus and potassium, are less soluble and therefore have a tendency to bind to soil particles and not infiltrate into the groundwater. In general, only half of the nitrogen applied is taken up in the plants, the rest either runs off or enters the groundwater. Between 1987 and 1988, nearly 7,400 tons of nitrogen fertilizer were sold in Southeastern Virginia.[38]

The main health problem associated with excessive nitrate intake is methemoglobinemia or "blue-baby syndrome." This condition occurs in infants when nitrates are reduced to nitrites in the blood. Nitrite reacts with hemoglobin to produce a compound that does not carry oxygen. Consequently, death from asphyxiation can occur. Nitrates are also suspected of causing the formation of carcinogenic nitrosamines in the stomach.[39] There have not been many documented cases of groundwater contamination by nitrates in Southeastern Virginia and there are no known health problems resulting from the few contamination cases that are on record. As mentioned earlier, high levels of nitrates in wells in a Virginia Beach neighborhood led to a warning not to consume well water and the eventual installation of public water lines. In that case, malfunctioning septic systems were the suspected source of the contamination. Relatively high nitrate concentrations have been detected in other shallow wells in rural Virginia Beach.[40] One well contained 14.0 mg/l of nitrate, which is well above the ten mg/l allowed by the Federal Primary Drinking Water Standards. The apparent increase in overall nitrate concentrations in this part of the city has been attributed to the impact of agricultural activities. In a 1985 survey of ten shallow household wells in the city of Chesapeake, one well was found to have a nitrate concentration of 12.75 mg/l. In this case, lawn fertilizers were cited as a probable source of contamination.[41]

Although commercial agriculture is the largest user of pesticides and fertilizers in Southeastern Virginia, substantial amounts are also used by industry, government and homeowners.[42] Homeowner use of pesticides and fertilizers may present a significant threat to groundwater in residential areas due to the high concentrations of treated lawns and gardens and, in some areas, the close proximity of domestic water supply wells.

Saltwater Encroachment

As noted earlier, the deeper confined aquifers of the eastern portion of the region are characterized by a naturally occurring eastward thickening wedge of saltwater. There is also naturally occurring saltwater in shallower aquifers in the immediate vicinity of tidal shorelines. In both the deep and shallow aquifers, excessive withdrawals of groundwater may cause an encroachment of brackish or salty water toward withdrawal points and the invasion of saltwater into previously uncontaminated groundwater. Encroachment may occur in the form of vertical "**upconing**" of brackish water from lower aquifers, or the lateral "**intrusion**" of saltwater from adjacent surface waters when groundwater levels drop below mean sea level. Saltwater intrusion and upconing occurs very slowly and may take years to materialize. Once it has occurred, it is usually irreversible. It is also important to note that the same process which causes the intrusion of saltwater from adjacent surface waters may also induce the intrusion of contaminants from polluted water bodies.

As is the case with the region's other potential groundwater contamination threats, man-induced saltwater contamination is suspected of occurring in Southeastern Virginia, but there is little supporting evidence. Staff of the Virginia Beach Public Utilities Department reports that, given the amount of withdrawals in certain parts of the city, saltwater intrusion is probably occurring. There have been sporadic reports that would support this speculation, but data are not sufficient enough to identify trends or delineate specific problem areas.[43] A 1986 analysis of well logs in the Great Neck area of Virginia Beach by the Virginia Beach Health Department indicates that excessive chloride levels have been present near the Lynnhaven River and Broad Bay shorelines for at least fifteen years.[44] Without pre-development data, however, it is impossible to determine whether these high levels are natural or are caused by residential pumping.

Saltwater intrusion is also suspected, but not proven, in the Churchland area of Portsmouth. In 1988, about twenty residents living along the Hampton Roads shoreline noticed an increased saltiness in their well water. The suspected source of this saltwater intrusion is the dewatering of a 140 acre Virginia Department of Transportation borrow pit dug for the construction of the Western Freeway.

It has been speculated that heavy pumping in the Franklin area has resulted in a westward movement of the saltwater wedge that is present in the deeper confined aquifers. To date, the fresh/salt water interface of the wedge has not been mapped and monitoring programs have not been adequate enough to show significant upward or downward trends in chloride content. Calculations based on mapped gradients and estimated porosity and permeability values indicate that the saltwater wedge may be advancing westward at a rate of 30 to 40 feet per year, and probably faster in the vicinity of major withdrawal points.[45] The saltwater encroachment issue is being addressed in an ongoing project to refine a regional groundwater flow model developed jointly by the USGS and the VWCB. This project is being conducted through the Southeastern Virginia Cooperative Regional Groundwater Program which is a cooperative effort, concerned primarily with groundwater quantity, involving the USGS, the SVPDC, the localities of Southeastern Virginia and the VWCB.

AREAS MOST SUSCEPTIBLE TO GROUNDWATER CONTAMINATION

The vulnerability of an area to groundwater contamination is determined by a number of influences including existing and potential sources of contamination; various anthropogenic influences (local regulations, politics, social values, and so on), and the hydrogeologic setting. This section focuses on local groundwater vulnerability as determined by **hydrogeologic setting** which is defined as the composite description of all hydrogeologic factors that influence groundwater movement in an area.[46] These factors include numerous physical characteristics and chemical processes.

It is not within the scope of this Handbook to conduct a regional analysis of local hydrogeologic factors to assess the vulnerability of the region's groundwater. With adequate resources and regional cooperation, however, such an analysis could be conducted using the **DRASTIC** mapping methodology developed by the National Water Well Association under contract to the EPA. The following is a brief description of DRASTIC. For a more complete description, the reader is referred to EPA publication EPA-600/2-87-035 entitled DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings.

The letters in DRASTIC stand for seven important mappable hydrogeologic factors which affect groundwater vulnerability. These factors are:

- Depth to water table
- (net) Recharge rate
- Aquifer media
- Soil media
- Topography
- Impact of vadose (unsaturated) zone
- Conductivity (hydraulic) of the aquifer

While not all inclusive, these factors were determined to include the basic requirements needed to assess the general pollution potential of different hydrogeologic settings. Moreover, these factors represent measurable parameters for which data are generally available without detailed reconnaissance.

Through the DRASTIC system, hydrogeologic settings are designated and mapped, and a ranking scheme is applied to determine relative groundwater vulnerability. Once completed, this evaluation can be used to help direct resources and land use activities to appropriate areas, and may also assist in setting groundwater protection, monitoring and clean-up priorities.

The DRASTIC methodology has been applied successfully in six counties in Virginia through a demonstration project funded by an EPA Groundwater Protection Grant. Due to the success of that project and in response to a recommendation in A Groundwater Protection Strategy for Virginia, the VWCB has instituted a program to provide technical assistance and training to localities for the local application of the DRASTIC methodology.

DRASTIC can be a powerful tool in managing groundwater. It is relatively easy to use and its effectiveness has been proven. However, several weaknesses in the

DRASTIC methodology should be noted. First, as mentioned above, DRASTIC does not account for all factors affecting groundwater vulnerability. Another drawback is that this methodology relies on several assumptions which limit its applicability. These assumptions and their limitations are described below:

- <u>A contaminant is introduced at the ground surface</u>. DRASTIC does not provide an accurate assessment of pollution potential where pollutants are discharged directly into groundwater.

- <u>A contaminant is flushed into the groundwater by precipitation</u>. The DRASTIC approach may not provide accurate results in areas where irrigation or other forms of artificial recharge occur.

- <u>A contaminant has the mobility of water</u>. In reality, a contaminant may be more or less dense than water and exhibit different flow characteristics.

- <u>An area evaluated using DRASTIC must be 100 acres or larger</u>. Often the flow of a contaminant is determined by site-specific characteristics.

Finally, due to data insufficiencies, it is often necessary to estimate when mapping the boundaries of the DRASTIC parameters or applying the numerical ranking system. Consequently, because the DRASTIC methodology often deals in generalities, it is inappropriate for site-specific applications.

A brief discussion of the DRASTIC factors and how they relate to groundwater vulnerability in Southeastern Virginia is presented below. Another vulnerability factor, the area of influence around a pumping well, which is not adequately addressed by DRASTIC is also discussed.

Depth to Water Table

Depth to the water table is one of the key factors determining the length of time it will take for a pollutant to percolate through the soil and unsaturated zone to the water table aquifer. With a longer residence time in the unsaturated zone, there is a greater chance that pollutant attenuation will occur. In Southeastern Virginia, water table depth can range from immediately at or near the surface in floodplains to as much as fifty feet below the surface in interstream upland areas.

Net Recharge

Net Recharge represents the amount of water per unit of land which penetrates the ground and reaches the water table. Net recharge is mainly determined by the rate of precipitation, but, in some areas, irrigation, artificial recharge and wastewater application may be contributing factors. Recharge water is the principal vehicle for leaching and transporting solid or liquid contaminants to the water table. Therefore, in most cases, the greater the recharge, the greater the potential for groundwater pollution. It is possible, however, for large amounts of recharge to dilute contaminants, at which point contamination potential may decrease. This possibility is not accounted for in DRASTIC.

Southeastern Virginia experiences a fairly uniform precipitation rate. However, localized net recharge can be affected by surface cover, soil permeability and slope. Consequently, net recharge rates might be less than average in densely developed areas having large amounts of impervious surface, in heavily vegetated areas, or in areas where soils have a high clay content. There may also be some slight variation in net recharge in the western portions of the region due to changes in topography. Net recharge can also be affected by local groundwater flow gradient. There may be an upward flow in discharge areas (rivers, wetlands and so forth) and a downward flow in the vicinity of pumping wells.

Aquifer Media, Soil Media and Impact of the Vadose (Unsaturated) Zone

The potential for groundwater contamination will depend on the degree of attenuation that occurs during the migration of the contaminant plume through the soil, the vadose or unsaturated zone, and the aquifer. Attenuation varies with different geologic materials, environmental conditions, and pollutant types. In general, fine- textured materials with low permeability values such as silts or clays can reduce infiltration and decrease the potential for contaminant migration. Conversely, coarser materials with high permeability such as sand, gravel or shell will encourage recharge and the infiltration of contaminants.

Soil is considered to be the upper weathered zone of the earth that averages six feet or less in depth. The unsaturated zone is the area below the soil zone and above the water table. Much of the material comprising these two zones in Southeastern Virginia, especially in the eastern portion of the region, consists of clay and silt and is poorly drained. More permeable sandy substrate, which is much more vulnerable to groundwater contamination, exists along ridges, or between stream valleys in the western portion of the region.

The two uppermost aquifers, the Columbia (water table) and the Yorktown-Eastover, are the most vulnerable to human induced contamination. The Columbia aquifer is the most vulnerable because it is usually the first to receive contamination. The Yorktown- Eastover aquifer is considered vulnerable by virtue of its high degree of interconnection to the Columbia aquifer. These aquifers consist mainly of fine to coarse sand and some mixed sand, gravel and shell. Not only do these materials have high permeability values, but the physical, biological and chemical processes responsible for attenuating pollutants are much less effective in a saturated environment. Therefore, materials comprising these two aquifers have a high potential for transmitting pollutants.

Topography

Topography refers to the slope and slope variability of the land surface. Depending on the topography of an area, a contaminant will either run off the land or remain long enough to infiltrate the soil. Areas with steep slopes will produce more runoff and will generally have low groundwater pollution potential. Conversely, flat or gentle sloping land will have greater pollution potential. For the most part, Southeastern Virginia is characterized by relatively low relief and would score high on this pollution vulnerability factor. There is, however, a notable difference in topography between the eastern and the western portions of Southeastern Virginia. In the western part of the region (west of the Suffolk Scarp), elevations range from twenty to 175 feet above mean sea level (MSL) and the land is characterized by gentle slopes overall with some moderately steep slopes along stream valleys. The eastern part of the region is characterized by poor drainage and elevations that seldom exceed 20 feet above MSL.

Hydraulic Conductivity

Hydraulic conductivity is the same as permeability, as defined earlier in this handbook. Permeability refers to the ability of an aquifer to transmit water which, in turn, controls the rate at which groundwater will flow under a given hydraulic gradient. The rate of groundwater flow controls the rate at which a contaminant will move through an aquifer. As mentioned, the Columbia and Yorktown-Eastover aquifers are comprised mainly of sand, gravel and shell. The materials have high hydraulic conductivity values.

Area of Influence

An **area of influence** is that area which overlies a well's cone of depression. In review, a cone of depression occurs where pumping has lowered the water table or the potentiometric surface of an aquifer, and has distorted the natural flow pattern of an aquifer. The size and shape of an area of influence will vary with pumping rates, recharge rates and the hydrogeology of an aquifer. An area of influence is vulnerable to contamination because pollutants introduced into this area are likely to be drawn into the well. The closer the source of pollution to a well, the sooner contaminants will be drawn into the water supply, and the less opportunity there will be for pollution attenuation. As mentioned previously, the 1986 amendments to the Safe Water Drinking Act require the states to develop programs which will guide localities in protecting the wellhead areas of public water supply wells. It is likely that such programs will delineate and require groundwater protection measures within areas of influence.

IDENTIFYING SPECIFIC HIGH RISK CONTAMINATION SOURCES

In addition to identifying areas that are particularly sensitive to groundwater contamination, it is also important to identify specific sources which have a high potential for causing contamination. Such analyses are called site-specific source evaluations. It is not within the scope of this Handbook to conduct such an analysis for the Southeastern Virginia region. However, the following briefly defines site-specific source evaluations and provides an example of how one might be implemented.

Site-specific source evaluations are used to systematically examine current and potential groundwater contamination problems associated with various land use activities. Through such evaluations, high risk land use activities are identified, located and mapped, compared with the location of sensitive areas, and assigned hazard rankings. Sites with high hazard rankings are then given high management priorities in the development and implementation of groundwater protection plans. Specifically, information gained from site-specific source evaluations might be used to determine priorities for a groundwater quality monitoring program, to determine target populations in a groundwater protection education program, or to assist in source identification in a groundwater pollution remediation effort.

The basic approach to conducting a site-specific source evaluation involves an examination of several factors including the relative hazards associated with the materials used by an activity; the method in which these materials are handled; proximity of an activity to designated sensitive areas; and the number of people that might be affected by a contamination incident. A diversity of methodologies representing a wide range of sophistication and resource requirements have evolved from this basic approach. For more information regarding different site- specific source evaluation methodologies, the reader is referred to an American Planning Association publication entitled Local Groundwater Protection.

One methodology which is somewhat simplified, but illustrates the basic approach to site-specific source evaluations was developed by the West Michigan Shoreline Development Commission (WMSRDC) as part of its Section 208 water quality planning program. The first step in the WMSRDC method is to assign hazard rankings to activities by their Standard Industrial Classification (SIC) code. These initial rankings may then be adjusted on a site-by- site basis with respect to a number of factors including volumes, toxicity and concentrations of hazardous materials present; level of waste pretreatment; and site history (such as previous record of previous spills). In the second step, the number of households that are within a one mile radius and may be affected by the activity is determined. The third step rates the site based on the number of households within a one mile radius that depend on groundwater for their water supply. In the last step, the site's distance to the nearest surface water is determined. Based on a evaluation system that considers the individual rankings from each of the four steps, each site is given a "low", "medium" or "high" groundwater pollution potential ranking.

The WMSRDC approach has its deficiencies; it does not consider groundwater flow patterns, nor does it consider the proximity of public water supply wells. These deficiencies not withstanding, this approach appears to be feasible in Southeastern

Virginia. The data required for all four steps should be available for most sites. Hazardous material use and toxic chemical release data are available for many sites under the "Community Right-to-Know" reporting requirements of Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986. In addition, records of reported spills are available through the VWCB Pollution Remediation Program. Data on the number of households within a one mile radius are available from the U.S. Census, while data on groundwater dependency should be available from local public utilities departments.

Site-specific source evaluations would not be appropriate in assessing saltwater encroachment since this source of contamination does not emanate directly from a land use activity. Areas that are potentially susceptible to saltwater intrusion or upconing can best be identified through monitoring and the development of groundwater flow models. Inflow/outflow analyses may also be used in shoreline areas as a first approximation of saltwater encroachment potential. Inflow/outflow analyses compare total recharge in an area to total withdrawals to estimate the magnitude of aquifer depletion.

RELATIONSHIP BETWEEN GROUNDWATER AND ENVIRONMENTALLY CRITICAL AREAS

Groundwater accounts for a significant amount of surface water flow. In humid areas, such as Southeastern Virginia, groundwater discharge may account for 70 to 80 percent of a stream's annual discharge.[47] Consequently, if contaminated, groundwater discharge to surface waters may pose a threat to environmentally critical aquatic areas. The greatest potential for contamination occurrs where groundwater provides a base flow or supporting water level for unique terrestrial or aquatic habitats, or where groundwater discharges to a water supply reservoir. Also, depletion of groundwater supplies can increase the concentrations of pollutants in streams by reducing flow.

Recent research has found the river systems support underground ecosystems known as **hyporheic zones** which are crucial to the health of surface water habitats.[48] These zones, which may extend fifteen to thirty feet below and many miles from each side of a stream channel, supply nutrients to surface waters and harbor subterranean organisms which periodically emerge and become part of the river's food chain. The introduction of contaminants into these zones may have a detrimental effect on the underground organisms and ultimately on the surface water habitat. Thus far, research on hyporheic zones has occurred primarily in the western United states. The nature and extent of these zones in the tidal estuaries and free-flowing streams of the Coastal Plain of the eastern United States has yet to be determined.

In Southeastern Virginia, environmentally critical aquatic areas that may be hydrologically connected to groundwater systems include lakes, free-flowing streams, wetlands, estuaries, coastlines and embayments. There have been a number of documented or suspected incidents of the degradation of surface water by contaminated groundwater. These incidents include seepage from a number of abandoned landfills, underground storage tanks and hazardous waste dumps along the Elizabeth River; suspected contamination of the Back Bay, Lynnhaven River and Lake Speight by malfunctioning septic systems; and suspected contamination of the Great Dismal Swamp by the abandoned Suffolk Landfill.

Although delineating environmentally critical areas may be relatively straight forward, determining the presence and source of polluted groundwater discharge may be difficult.

LOCAL GROUNDWATER PROTECTION TECHNIQUES

There are numerous strategies that can be implemented by local governments to prevent groundwater contamination. However, for a community to develop an effective groundwater protection program, it must prepare a groundwater management plan consisting of community-specific goals and objectives, and locally appropriate management techniques. In formulating goals and objectives, a community must determine local groundwater protection needs and the appropriate scope of a local groundwater protection program. The determination of protection needs will be based on local hydrogeology, existing and potential threats to the groundwater system, and patterns of water use. In determining the appropriate scope of a local groundwater protection program, consideration must be given to local dependence on the groundwater supply, other community goals that may conflict with groundwater protection, legal constraints, existing state and federal regulatory programs, and the values and priorities of the local citizenry.

Once a community has assessed its groundwater protection needs and has formulated the goals and objectives of its groundwater protection plan, it is then ready to select specific management techniques. These techniques must be carefully selected and combined in such a way as to maximize effectiveness in achieving objectives and to minimize costs. In general, groundwater protection techniques can be grouped into two broad categories: sensitive area controls and source controls. The following description and evaluation of techniques has been separated into these two categories. It is important to note that, in most groundwater protection programs, both types of strategies are implemented in concert.

To date, no locality in Southeastern Virginia has developed a formal groundwater protection program. Given the variation in Southeastern Virginia with respect to groundwater dependence, contamination threats and, to a lesser degree, hydrogeology, it is likely that the content of local groundwater protection programs would differ significantly. It is not the intent of this Handbook to recommend specific protection programs for individual localities. This can only be done through the local planning process. The purpose of this Handbook is to provide information that can be used in formulating local goals and objectives and in selecting appropriate management techniques. Thus far, this Handbook has presented information on local hydrogeology; existing groundwater use; federal, state and local roles in protecting the region's groundwater; and local groundwater areas of concern. In this section, a number of groundwater protection strategies will be identified and, where possible, evaluated with respect to their potential usefulness in local groundwater protection programs.

The discussion of control techniques has been limited to those that would protect the Columbia and Yorktown-Eastover aquifers. This is because these aquifers are the most susceptible to contamination from overlying land use activities, and they serve as the principal source of recharge to the region's deeper aquifers. In addition, State regulations ban the use of deep underground injection wells for waste disposal, thus preventing the direct introduction of contaminants into the deeper aquifers. It is therefore reasonable to assume that protection of the Columbia and Yorktown-Eastover aquifers will prevent contamination of the aquifers to which they are hydrologically linked.

SENSITIVE AREA CONTROLS

Through the identification of sensitive areas, management techniques can be applied to locations where groundwater resources require the greatest protection. In delineating sensitive areas, consideration is generally given to one or more of the following criteria: importance as a recharge zone; location within a pumping center's area of influence; existing groundwater quality; vulnerability to contamination; existing or intended uses; and the interrelationship between groundwater and environmentally critical areas.

A locality may want to assign protection priorities to different types of sensitive areas or to differentiate zones within individual sensitive areas. Areas with the highest protection priorities would be subject to more stringent controls. For example, through a detailed hydrogeologic survey, concentric zones can be identified within areas of influence which reflect the time required for groundwater to reach a pumping center. These zones, commonly referred to as time-related capture zones, could be used to assess water quality threats to a pumping center and to assist in the development of protection techniques. Through the designation of time-related capture zones, land use controls within an area of influence can be fashioned so that their stringency increases as groundwater flow time to a pumping center decreases.

Not all of the criteria used in delineating sensitive areas are relevant to Southeastern Virginia. For instance, it would be difficult to delineate specific recharge areas. This is because, unlike other physiographic provinces where discrete recharge zones can be identified, recharge occurs over large portions of the region through vertical leakage from the Columbia (water table) aquifer.

Another obstacle to sensitive area identification is that the data required to map sensitive areas may not be available. In Southeastern Virginia, this would be the case when attempting to determine areas of influence around major pumping centers, ambient water quality, and the relationship between groundwater and environmentally critical areas. Delineation of areas of influence around public water supply wells should be facilitated by the State's wellhead protection program which is being developed in accordance with the 1986 amendments to the Safe Water Drinking Act.

As mentioned previously, one potentially useful approach to identifying areas that are particularly vulnerable to groundwater contamination is the DRASTIC mapping system. By using this technique, readily available data can be used to help determine the groundwater pollution potential of and to assign protection priorities to various hydrogeologic settings within a locality.

A sensitive area identification approach may be controversial in that areas not designated as being sensitive will receive lower levels of protection. It could therefore be implied that the portions of an aquifer receiving less protection will be allowed a certain amount of contamination. This situation should be avoided through adherence to the State's antidegradation policy which is intended to ensure that future groundwater needs will be met through the maintenance of existing groundwater quality.

Once identified, sensitive areas can be protected by a mix of land use management and source-specific controls. Source-specific controls, which are generally most applicable in built up areas, might be applied in designated sensitive areas only, or uniformly throughout an entire locality. Such strategies will be discussed later in this chapter. Land use controls are best suited to controlling future land uses within sensitive areas that are undeveloped. The following is a description and evaluation of land use management techniques that might be used to protect a community's groundwater resources.

Traditional Zoning

In general, a traditional zoning ordinance delineates zoning districts, lists permitted and conditional uses in each district, and establishes basic development requirements for each district (i.e., minimum setbacks, side yards, lot size, lot coverage and building height). As previously mentioned, the 1988 session of the Virginia General Assembly acknowledged the importance of zoning in protecting groundwater by amending Section 15.1-489 of the Virginia Code to require local governments to consider groundwater protection in the preparation of local zoning ordinances.

Traditional zoning can be used to prevent groundwater contamination through the creation of new zoning districts to protect sensitive areas or through the strengthening of restrictions in existing zoning districts which contain designated sensitive areas. In either case, groundwater protection could be achieved through use prohibitions and restrictions; density restrictions; and limits on the amount of impermeable surface.

Use prohibitions or restrictions can be imposed for activities that have a high potential for groundwater contamination (e.g., septic systems, businesses using or storing hazardous materials, waste management facilities, borrow pits, outside materials storage, and so forth). A locality can restrict such uses through a special or conditional use permitting process. Through this process, a request for a use can be denied outright, or special conditions can be imposed which are based on specific issues and concerns raised about a particular site. Such conditions might stipulate facility design requirements and best management practices which minimize the potential for groundwater contamination. For example, a locality may prohibit commercial and industrial establishments from using septic systems unless certain discharge quantity and quality conditions are met. Along with imposing prohibitions within new or existing zoning districts, a locality may want to incorporate new guidelines into its zoning ordinance for amortizing existing prohibited uses.

Zoning may also impose density restrictions through minimum lot size and maximum lot coverage requirements. Low density zoning may be necessary in sensitive areas to ensure that the assimilative and filtrative capacity of the soil and unsaturated zones are not exceeded. Low density zoning is most commonly used to prevent groundwater contamination in areas where hydrogeologic conditions limit the use of septic systems. Requiring a minimum lot size reduces the density of septic systems and limits the total quantity of effluent entering the ground.

By minimizing the amount of impermeable surface within a zoning district, the natural recharge characteristics of a site can be preserved. Maintaining the integrity of the natural groundwater flow system is particularly important on sites where pumping might otherwise encourage the encroachment of saltwater or man-made contaminants.

In a 1989 survey conducted by the Virginia Council on the Environment, local governments cited traditional zoning as one of the few management tools currently being used by Southeastern Virginia localities to prevent groundwater contamination. Conditional zoning and special use permits are sometimes used to impose conditions on proposed uses which may have adverse effects on groundwater. In addition, large lot zoning is commonly used to ensure compliance with or exceed Virginia Department of Health standards in areas that necessitate the use of on-site septic systems and wells.

There are several drawbacks to using traditional zoning, as well as the innovative zoning techniques described below, to protect groundwater. A principal disadvantage is that such techniques may be challenged on the grounds that they constitute a taking of property without compensation. To avoid such challenges, zoning ordinances should conform to well prepared, publicly accepted and technically sound groundwater management plans. Such plans should be incorporated in and be consistent with a community's comprehensive plan. Another potential problem with land use controls is that recharge to a community's groundwater system may occur across political boundaries. In such cases, groundwater contamination may occur as a result of land use management practices in a neighboring jurisdiction that do not protect groundwater. A further disadvantage to using zoning techniques to prevent groundwater contamination is that they are ineffective in controlling the activities of state and federal agencies.

Innovative Zoning Techniques

Innovative zoning techniques that might be incorporated into the existing zoning ordinance to protect groundwater resources include **overlay zoning, Planned Unit Development, transfer of development rights,** and **performance standards.** The following provides a brief description of each.

Overlay zoning offers an alternative to the sometimes static nature of traditional zoning. Overlay zones are not intended to replace or change underlying zoning requirements. Instead, they are superimposed on existing zoning districts to provide additional land use regulations. In the context of groundwater protection, overlay zones might be applied in designated sensitive areas to impose additional use restrictions, runoff and groundwater contamination performance standards, tighter septic system regulations and stricter site plan review procedures.

Planned Unit Development (PUD) is a technique by which subdivision and zoning regulations apply to an entire project rather than to individual lots. This allows site designs which cluster development and maximize areas for the development of public facilities and the preservation of open space. PUD can be used to maintain the natural recharge characteristics of a site, or direct development away from portions of a site that are vulnerable to groundwater contamination or where groundwater discharges to surface waters.

Through the transfer of development rights (TDR), a property owner in designated areas, known as "sending zones," may transfer (sell) the development rights granted to him under the zoning ordinance to a property owner in a designated "receiving zone" where conditions for development are more appropriate. A TDR program could be used to shift development densities and potential contamination threats away from designated sensitive areas. The use of TDR might not be appropriate in every community. In order for development rights to be marketable, development pressure and limited availability of land are needed; these conditions do not exist in all Southeastern Virginia localities. In addition, the use of TDR is not permitted under State enabling legislation. It is anticipated, however, that this issue will be addressed in the 1989 Virginia General Assembly.

In contrast to the conventional use and density restrictions imposed under traditional zoning, the intensity of development is sometimes controlled by the application of environmental performance standards. Through the use of such standards, selected uses or mixes of uses are allowed within a zoning district as long as they meet certain "performance" criteria. Examples of performance standards that might be used to protect groundwater include:

- imposing different septic system design requirements depending on the hydrogeologic characteristics of a site;

- ensuring adequate recharge by requiring that runoff volumes not exceed pre-development levels;

- employing a groundwater modelling program on sites that would be served by septic systems to ensure that nitrate levels would meet appropriate standards at the property line and at a drinking water well.

An advantage of performance standards is that they allow considerable flexibility with respect to site design and use. The primary disadvantage to their use is that the data needed to demonstrate that performance criteria are being met may not be readily available. In addition, the use of certain performance standards may not be allowed under state enabling legislation.

Other Land Use Control Ordinances

Groundwater protection provisions can also be incorporated into other land use control regulations including subdivision, erosion and sediment control, site plan review and stormwater management ordinances. A brief discussion on how each might be revised is found below.

A locality's subdivision ordinance can be used to require developers to set land aside or utilize design standards and engineering practices to protect groundwater. For instance, subdivision regulations might be used to reserve designated sensitive areas for eventual acquisition by a locality, or to ensure the provision of stormwater control practices which would maintain the natural groundwater flow characteristics of a site. In addition, subdivision controls might be used to ensure that certain stormwater management facilities, such as infiltration devices or wet detention basins, are not located where they might contaminate groundwater supplies. A subdivision ordinance should require that an evaluation of soils for well and septic system suitability be conducted before land is subdivided.

A locality may wish to strengthen its erosion and sediment control ordinance to better regulate land disturbing activities in sensitive areas. If not properly controlled, site development may disrupt the natural flow of the groundwater system and encourage the introduction of contaminants. This would most likely occur where the water table lies close to the surface, and where increases in impermeable surfaces inhibit recharge and encourage the encroachment of saltwater or man-made contaminants.

A locality may want to consider revising its site plan review ordinance, or zoning ordinance where such an ordinance has not been adopted, to incorporate certain groundwater protection provisions in the site plan review process. In reviewing a site plan for possible groundwater impacts, consideration should be given to the on-site location of potential contamination sources such as septic systems, underground storage tanks and surface waste impoundments. Such facilities should be located away from steep slopes, surface waters, flood zones, stormwater runoff pathways, and water supply wells. Site plan review requirements might also require developers to conduct site-specific studies to ensure groundwater protection. These studies might include hydrogeologic impact analyses, hazardous materials use and disposal plans, or general groundwater protection plans.

The 1989 Virginia General Assembly passed legislation which enables local governments to adopt stormwater management ordinances which require the submission and approval of site-specific stormwater management plans prior to any non-exempt development activity. If adopted, a stormwater management ordinance might require that site-specific plans describe the extent to which proposed stormwater control practices and the hydrologic characteristics of the proposed development will affect local groundwater flow and quality.

Land Acquisition

Occasionally, a locality will use its eminent domain powers for the fee simple acquisition of sensitive areas. This is usually done where (1) long-term protection is absolutely essential to protect groundwater quality; (2) stringent land use controls on private property are politically or legally unacceptable; or (3) a combination of mutually supportive purposes can be achieved (i.e., non-point source pollution control, provision of recreation, wildlife protection or wetlands preservation). As mentioned previously, public acquisition might be achieved through the subdivision ordinance by requiring developers to reserve environmentally sensitive portions of sites for eventual acquisition by the locality. Public acquisition is often not practical for a locality due to the high acquisition and long-term maintenance costs involved.

In lieu of fee simple acquisition, a locality may elect to purchase development rights or purchase restrictive easements in sensitive areas.

Tax Incentives

Localities may consider lowering the property tax assessment on land used for the purpose of protecting groundwater supplies. This procedure is commonly known as use-value taxation. The State Code allows the use-value taxation of open space preserved for the protection of natural resources as long as certain conditions are met.

SOURCE CONTROLS

As previously mentioned, most local groundwater protection programs consist of a mix of sensitive area and source controls. Often, source controls are incorporated into land use management strategies designed to protect sensitive areas. Under some circumstances, however, a locality may choose to adopt community-wide source controls rather than sensitive area controls. For example, source controls may be preferred in communities where sensitive areas are not easily delineated because local hydrogeologic characteristics are either too homogenous or not well defined. A community may also find that source controls are more effective where political support for sensitive area controls is lacking.

Most of the high priority groundwater contamination sources identified for this Handbook are already subject to State and federal regulations. A locality may decide, however, that regulations imposed on certain sources do not adequately address community-specific groundwater contamination threats. Therefore, the source controls discussed below focus on those which a locality might use to supplement controls imposed by higher State or federal agencies.

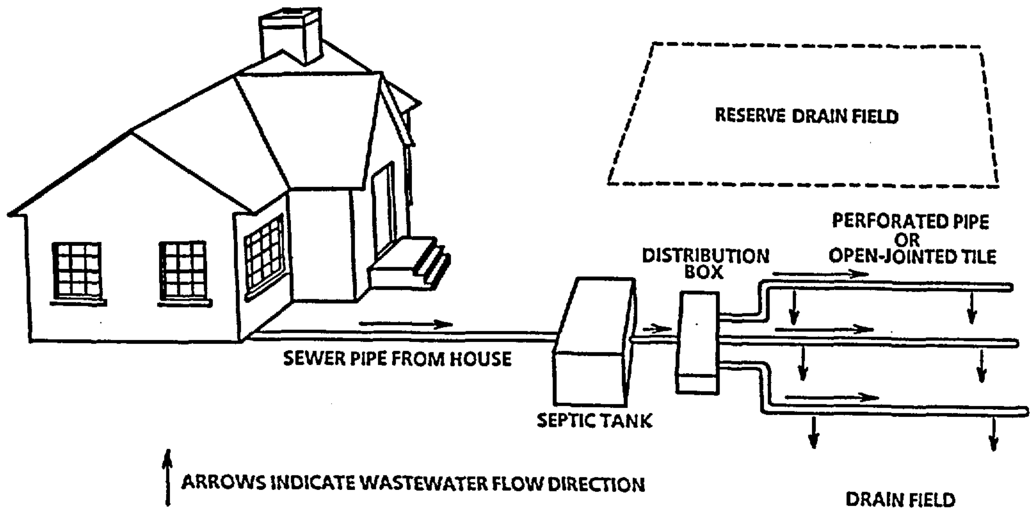
Source controls can be structural or nonstructural and may include procedural and reporting requirements. The following describes possible controls for those sources of pollutants that have been identified as the greatest threats to groundwater in Southeastern Virginia.

Septic Systems

Existing Regulations and Initiatives

On-site domestic and commercial sewage disposal systems which do not discharge to surface waters are regulated by the Virginia Department of Health (VDH). These systems mostly include septic systems and mass drain fields. Before on-site sewage disposal systems are constructed, permits must be obtained from locally-based VDH sanitarians. Before permits are issued, the sanitarian will review the proposed design and site characteristics to ensure that the system will function adequately. Site characteristics considered in this review include topography; percolation rates; standoff distance to water table; depth to restrictive layers below a system; slope; and setback distances to potentially sensitive site features such as streams, lakes, wells, shellfish waters, and so forth. Systems are inspected at the time of installation to ensure compliance with VDH regulations. No routine follow-up visits are conducted to monitor system operation. If a complaint is received of a failing system, the VDH will investigate. If a failing system is found, the owner will be required to take corrective action. In some localities, the VDH will inspect on-site sewage disposal systems as a service to lending institutions when homes are sold. These inspections are not required by Virginia law, however. Occasionally, the VDH will conduct sanitary surveys of specific geographic areas in response to the needs of local governments. These surveys evaluate existing systems for overt failures (i.e., sewage above ground) and are usually conducted to identify areas in need of public sewer systems. Such a survey has been conducted in the community of Sandbridge in Virginia Beach and is currently being conducted in the Lake Speight subdivision in Suffolk.

COMPONENTS OF A HOUSEHOLD SEPTIC SYSTEM



Septic systems for the disposal of industrial wastewater are regulated by the VWCB. There is no separate program for regulating industrial septic systems. Such systems are subject to the general requirements of the Virginia Pollution Abatement permit program because they do not result in point source discharges to surface waters. Before a VPA permit will be issued, it must be demonstrated that a proposed industrial septic system will protect the beneficial uses of groundwater. Groundwater monitoring is often a permit condition. VPA permits, or No-Discharge Certificates where still applicable, are periodically reviewed to ensure that a system continues to operate properly.

In addition to the VDH and VWCB regulations, Tidewater localities are subject to septic system standards contained in the implementing regulations of the Chesapeake Bay Preservation Act. These standards state that all septic systems in designated Chesapeake Bay Preservation Areas must be pumped out every five years and any new systems must be constructed with a 100 percent reserve drainfield capacity.

The Virginia Cooperative Extension Service (VCES) is the educational arm of the State's two Land-Grant Universities (Virginia Polytechnic Institute and State University, and Virginia State University). The VCES is a partnership of federal, State and local organizations which provides public education opportunities in a number of areas. Field staff consists of county and city Extension Agents, and research staff is comprised of faculty at both universities. The VCES has recently incorporated groundwater protection into its agriculture and natural resources program unit. The VCES groundwater education program addresses a number of groundwater protection issues including management of on-site septic systems.

Alternative Local Strategies

The existing State septic system regulations may not adequately address a locality's groundwater protection needs for several reasons. As mentioned, the VDH does not conduct routine inspections to ensure the proper operation of systems. In addition, the primary focus of the VDH on-site sewage disposal regulations is to prevent the ponding of sewage in soils that do not percolate. The protection of groundwater receives less attention. In some communities, septic systems have been allowed where ponding may not occur, but where highly permeable soils and shallow water tables create conditions that are conducive to groundwater contamination. Another potential threat to a community's groundwater is the existence of unpermitted domestic or commercial/industrial systems which do not meet permitting criteria. Finally, under existing VDH and VWCB permitting regulations, there is insufficient attention paid to ensuring compliance with groundwater standards.[49]

To protect local groundwater from contamination from septic systems, a locality might eliminate the need for septic systems by extending public sewer lines to designated sensitive areas. Where this is not practical, a number of local strategies can be employed which supplement the State septic system regulations. Possible density controls were discussed previously. There are also a number of siting, design and operation controls which might be incorporated into zoning, subdivision, site plan review or ordinances, or might serve as the basis for a separate on-site waste disposal management ordinance. In addition, public education programs can be useful in promoting proper operation and maintenance of septic systems. Possible siting, design, operation and education strategies that might be implemented to prevent groundwater contamination from septic systems are discussed below. Some of these strategies will require new State enabling legislation before they can be implemented by Southeastern Virginia localities.

Septic system siting and design standards that localities might use to protect groundwater include:

- Exceed VDH septic system minimum separation distances where necessary to protect groundwater.

- Require a minimum separation distance between the septic system and the water table which takes maximum water table height into account.

- Require 100 percent reserve drainfield capacity which would be available for the construction of a second drainfield should the first field fail. (This requirement already exists for Chesapeake Bay Preservation Areas.)

- Require that each septic system have a split drainfield or duplicate drainfields. This would allow flow to be periodically diverted to the other half of a single dainfield or to a second drainfield. By diverting flow, a drainfield can "rest" thus allowing substances which may clog a system to degrade.

- Prohibit storm drain connections to septic systems.

- Require sufficient and convenient vehicle access to the tank cover for septic system maintenance and inspection purposes.

Locally implemented septic system operation and maintenance controls might be implemented community-wide or in specified on-site sewage management districts. These districts, which are discussed in detail in the 1983 update of the Hampton Roads Water Quality Management Plan and were encouraged by a resolution passed by the 1989 Virginia General Assembly, could be established in designated problem areas to monitor, or assume responsibility for, the operation and maintenance of septic systems. Should a locality assume management and operation responsibilities within a district, it might consider forming a public utility for that purpose. Alternative operation and maintenance controls are as follows:

- Prohibit the disposal of materials in septic systems which have high groundwater pollution potential. Such materials might include hazardous materials as defined by the National Fire Prevention Code; petroleum products; pesticides; embalming fluids; photography developing fluids; medical wastes; septic tank cleaning compounds; drain cleaners; disposable diapers and coffee grounds.[50]

- Require that septic systems be pumped out and inspected every five years. (The pump-out requirement already exists for Chesapeake Bay Preservation Areas.) Inspections might be conducted by a locality, or by certified private engineers or sanitarians. In the latter case, a mail-in certification system could be employed.

- If a locality implements a five year pump-out requirement, it may consider assuming the responsibility by contracting out septic tank pumping to a private firm and then billing property owners. Through this approach, full compliance with the pump-out requirement can be assured and system failures can be minimized.

- If split or duplicate drainfields are mandatory, require that they be alternated on a regular basis, perhaps annually or semi-annually.

- Institute mandatory pre-occupancy inspections of septic systems when properties change hands.

Public education programs aimed at promoting proper operation and maintenance of septic systems might reach targeted audiences through seminars, a detailed septic system owner's guide, brochures and fliers, public service announcements, local cable access programming, traveling exhibits, and speaker programs. Such programs might contain the following elements:

- Information on why septic systems fail, and how to locate, inspect and pumpout systems.

- Promotion of water conservation measures to reduce the amount of wastewater that enters the ground and to extend the life of septic systems.

- Cost figures which demonstrate the savings that septic system owners can realize in the long run through proper operation and maintenance procedures.

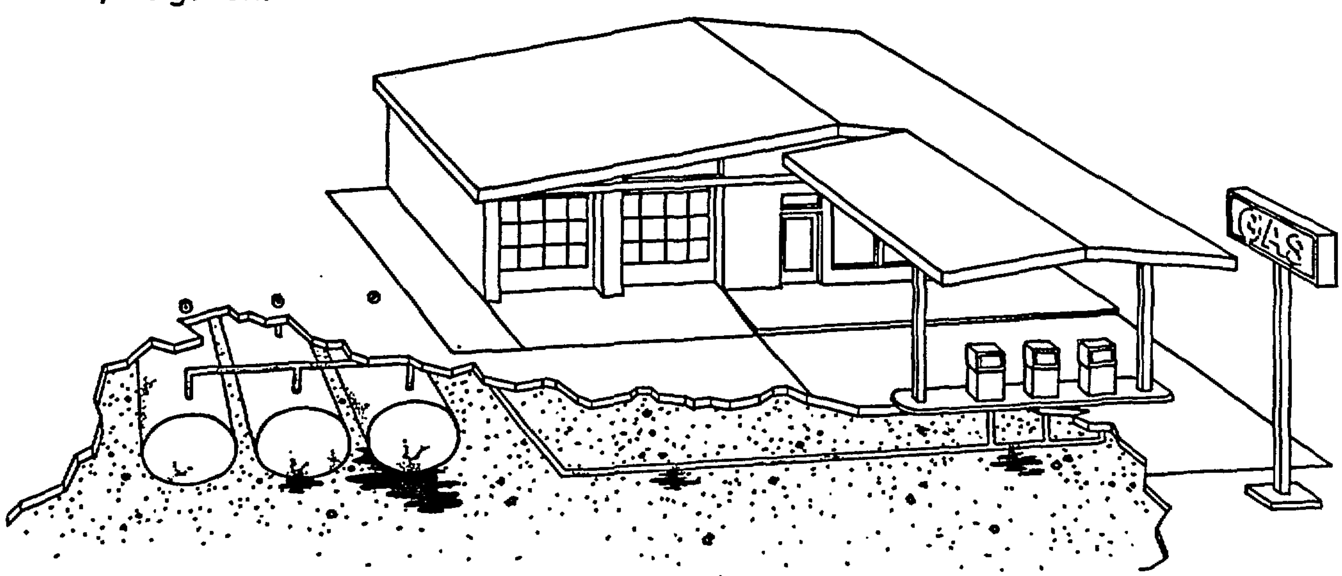
- A listing of the materials that should not disposed of in septic systems.

- The required posting of notices at commercial and industrial establishments dependent on septic systems to alert business owners, employees and customers of the need to keep certain substances out of the septic system.

<u>Underground Storage Tanks</u>

Existing Regulations and Initiatives

The 1984 amendments to the Resource Conservation and Recovery Act (RCRA) require the regulation of USTs. Under the Federal UST Program, which is administered by the EPA, states are required to gather data on existing USTs and the EPA is responsible for developing regulations to implement performance criteria for new USTs. To meet the federal data gathering mandate, the VWCB administers a tank notification program which requires the registration of all non-exempt USTs that were in the ground on or after May 8, 1986. Registration is not required for certain types of USTs that are exempt from RCRA regulations including heating oil tanks of less than 5,000 gallons and any farm and residential USTs storing less than 1,110 gallons.



In conformance with the 1984 RCRA amendments, the Virginia General Assembly enacted Articles 9 and 10 of the State Water Control Law to (1) establish a VWCB-administered Virginia UST program that is at least as stringent as the Federal UST Program, (2) establish financial responsibilities for tank owners, and (3) create the Virginia Petroleum Storage Tank Fund to be used in conjunction with the Federal Leaking Underground Storage Tank Fund.

In 1988, EPA regulations addressing technical standards for installation, upgrade, closure and corrective action became effective. The EPA regulations were incorporated into the Virginia UST Program with some minor modifications that increase the stringency of the State regulations. Under the new regulations, all owners of existing, non-exempt USTs are required to test and protect their tanks, identify and correct leaks, and clean up spills and releases by 1998. In addition, newly installed tanks are required to meet design, construction and monitoring standards that prevent leaks and overflows. These regulations will be implemented at the local level by permitting programs administered by local building inspectors. The VWCB conducts random inspections to uncover violations of the Virginia UST Program.

Alternative Local Strategies

Although the Virginia UST Program exceeds federal regulations and is a vast improvement over pre-existing UST controls, it does have several deficiencies. One drawback to the program is that monitoring program compliance is limited to random inspections by a short-handed VWCB staff. Only a very small percentage of violations can be uncovered under the present system. Another deficiency of the program is that heating oil tanks of less than 5,000 gallon capacity and farm and residential tanks storing less than 1,100 gallons are unregulated. It has been speculated that, of all types of USTs, home heating oil tanks pose the greatest threat to groundwater.

Several controls that might be implemented by local governments to supplement State UST regulations are listed below. Applicable siting strategies were discussed in the Sensitive Area Controls section.

- Develop a program through which local staff assist State personnel in monitoring compliance with the Virginia UST Program.

- Institute a local program regulating smaller tanks that are exempt from the Virginia UST Program. Such a program might include many of the issues addressed in the State program including permitting of installations, construction standards, testing, upgrades, repairs and closures.

- Prohibit below-ground residential heating oil tanks and establish a program through which existing tanks are phased out at the end of their anticipated lifetimes.

- Institute a public education program to inform business owners of the existence and requirements of the Virginia UST Program.

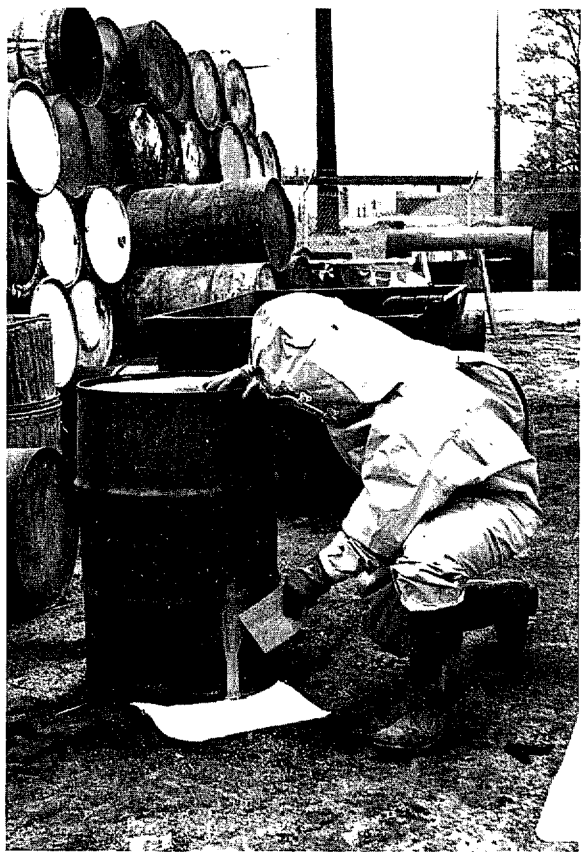
Spills and Improper Disposal of Hazardous Materials

Existing Regulations and Initiatives

Several State and regional agencies work together in the prevention of and emergency response to spills and improper disposal of hazardous materials.

The Virginia Department of Waste Management (DWM) is responsible for promulgating regulations governing the transportation of hazardous materials. These regulations, which are consistent with the federal Hazardous Materials Transportation Act, designate the manner in which hazardous materials should be loaded, unloaded, packed, identified, marked, placarded, stored and transported.

The DWM also regulates the handling of hazardous wastes through its Hazardous Waste Management Program. Under this program, the DWM oversees several activities including hazardous waste management facility site certification and permitting, the RCRA "cradle-to-grave" hazardous waste disposal regulations, and accidental spill or release reporting procedures. The hazardous waste management facility site certification process reviews potential off-site impacts of a proposed facility and involves extensive local government involvement, preparation of an environmental impact statement and a public hearing process.



The hazardous waste facility permitting process ensures that facilities meet operation and design standards mandated in the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA. RCRA requires the "cradle-to-grave" regulation of hazardous waste generation, transportation, treatment, storage and disposal. Through this system, which is administered by the DWM in Virginia, all non-exempt hazardous waste must be accompanied from its point of generation to its ultimate disposal site by a manifest. All facilities generating more than 100 kilograms per month of hazardous waste are subject to the manifest requirement.

DWM accidental spill or release reporting regulations, required under the Superfund Amendments and Reauthorization Act of 1986, provide guidelines for the reporting of all hazardous substance releases exceeding "reportable quantities" established by the EPA. These guidelines dictate the types of information that should be included in an initial notification, and who should be notified for different types of releases.

Under the Virginia Emergency Services and Disaster Law of 1973, as amended, the Virginia Department of Emergency Services (VDES) provides guidance, support and resources to local governments in dealing with all types of disasters, including both in-transit and on-site hazardous materials spills. In the event of a spill, the VDES Technological Hazards Branch (THB) can provide information to local emergency response personnel on product identification, specific chemical data or incident mitigation. THB personnel, or a multi-agency Hazardous Materials Emergency Response Team coordinated by the VDES, can provide on-scene assistance by either providing technical guidance or participating in control actions. Final cleanup is usually handled by contractors or the DWM.

The VWCB Pollution Remediation Program (PReP) was organized to investigate pollution incidents that impact or have the potential to impact State waters. PReP maintains a 24-hour hotline to receive reports. When a call is received, PReP personnel evaluate the report and determine appropriate VWCB response, or notify another agency if the incident does not fall under VWCB purview. When a groundwater pollution incident is identified, remediation plans are developed by the responsible party for review by VWCB personnel.

Although not mandated by State or federal regulations, the proper disposal of household hazardous wastes is addressed by programs administered by the Virginia Department of Mines, Minerals and Energy (DMME), the Southeastern Public Service Authority (SPSA) and the DWM. The DMME administers a program which provides used oil collection centers across the state. At the regional level, SPSA has sponsored and the DWM has provided technical assistance and support to a series of Household Hazardous Waste Clean-Up Days which have been held at various locations throughout Southeastern Virginia. Through these events, residents are encouraged to bring hazardous wastes to a central collection site for identification, packing and shipment to a permitted hazardous waste management facility. In addition, SPSA has established a permanent household hazardous waste collection facility at the SPSA Chesapeake Transfer Station. SPSA has also hired a consultant to investigate the possibility of implementing a hazardous waste collection program for small businesses not regulated under RCRA.

Alternative Local Strategies

There are several ways in which local governments can supplement and support federal, State and regional efforts to prevent groundwater contamination from accidental spills or improper disposal of hazardous materials. As noted above, only hazardous waste management facilities are subject to State and federal siting and design regulations. The siting and design of other facilities which use hazardous substances and/or generate hazardous wastes can be controlled locally by employing overlay zoning or a special use permitting process. Design requirements that might be imposed in an overlay zone or as conditions of a special use permit include enclosure of storage areas and stockpiles; provision of curbs, drains and sumps to prevent contaminant runoff; and installation of leak detection devices.

Another potential strategy is the adoption of a hazardous materials storage ordinance. Such an ordinance has been implemented successfully elsewhere in the country, but would probably require new enabling legislation before it can be adopted in Southeastern Virginia. This ordinance would require businesses and industries to obtain a local permit for the storage of all hazardous materials meeting State and/or federal definitions. The ordinance would establish installation, containment and monitoring standards that would have to be met by new and existing facilities before this permit is issued. The ordinance would also require facility operators to inventory the types and quantities of materials to be used, and the method in which these materials are to be stored, separated and monitored. Periodic local inspections might also be required under this ordinance.

Local governments might also implement strategies to control hazardous waste disposal from generators not regulated under RCRA. These include businesses which generate less than 100 kilograms of hazardous waste per month as well as homeowners who cumulatively dispose of large quantities of hazardous materials. Given the sheer numbers of such waste generators, a local regulatory program which requires these generators to account for their disposal practices would be impractical. A more practical approach would be to implement an educational program through SPSA which disseminates information on proper hazardous waste management. This program could:

- Describe the potential effects of small amounts of hazardous materials on groundwater resources.
- Instruct businesses and residents in the proper use, handling and disposal of hazardous materials.
- Encourage businesses and residents to avoid using illegal dumps and to report such dumps to the proper authorities.
- Inform citizens of the existence of the DMME used oil program and the SPSA household hazardous waste collection program.

- Encourage individuals and businesses to substitute "safe" products for commonly used hazardous and toxic substances.

An educational program might also be developed that is aimed at the regulated community. This program would describe existing regulatory efforts and encourage non-exempt generators to comply with State and federal regulations.

Surface Waste Impoundments

Existing Regulations and Initiatives

The VWCB regulates the construction and operation of surface impoundments under either the NPDES or the Virginia Pollution Abatement permit programs. NPDES permits are required for those surface impoundments which discharge to state waters. Under the VPA program, which has recently replaced the no discharge certification program, permits are required for those non-discharging impoundments which rely on evaporation or store waste for eventual land application. In conformance with federal regulations promulgated under the 1984 RCRA amendments and in adherence to the State anti-degradation policy, the VWCB requires that design and performance standards be met for all new surface impoundments requiring NPDES or VPA permits. These standards address impoundment size, and location relative to State waters, including groundwater. Groundwater monitoring may also be required as a permit condition. Under federal law, liners are required only for those impoundments which store wastes that are regulated under RCRA. However, the VWCB may require liners for other facilities as a permit condition. In situations where there is a high potential for groundwater contamination, the VWCB may also impose stricter design and performance standards on existing facilities requiring NPDES or VPA permit renewal.

Alternative Local Strategies

The federal and State laws governing surface waste impoundments are generally effective in preventing groundwater pollution. The most effective strategies that local governments can implement to supplement State and federal regulations are sensitive area controls discussed previously. There is, however, at least one regulatory gap which could be filled by a local source-specific control. Under current laws, liners, the primary defense against groundwater pollution, are required only for impoundments containing wastes regulated by RCRA. Materials exempt under RCRA that are commonly found in impoundments include domestic sewage; animal wastes; point source industrial wastewater discharges; materials which are considered primary parts or interim byproducts of manufacturing processes; and other materials which are always used, reused, recycled or reclaimed by all companies within an industry. Although the VWCB often requires liners for impoundments containing such materials as a condition for permitting, localities may want to reinforce State efforts by requiring that all surface waste impoundments, either throughout the community or in designated sensitive areas only, be equipped with liners. This could be accomplished through special use permitting or overlay zoning.

Landfills

Existing Regulations and Initiatives

As previously mentioned, RCRA requires entities generating significant quantities of hazardous wastes to manage and track these wastes and to dispose of them in RCRA-permitted hazardous waste facilities. Due to these regulations, large quantities of hazardous wastes have been directed away from landfills. However, there are still significant quantities of hazardous substances found in common municipal waste which can be leached out of a landfill and cause significant groundwater contamination. The 1984 amendments to RCRA required the EPA to provide states with guidelines for permitting new and existing sanitary landfills. In 1989, the DWM adopted the EPA guidelines and promulgated new solid waste regulations. These regulations promote groundwater protection by regulating proper siting, design, management and closure of landfills. As result of these regulations, new landfills must be developed away from areas that are susceptible to groundwater contamination. Both new and existing landfills must incorporate new design and operation standards such as double clay or synthetic liners; leachate collection, treatment and disposal systems; and groundwater monitoring and corrective action programs. Existing landfills will have until 1992 to come into compliance. The regulations also stipulate specific procedures for landfill closure including a ten year groundwater monitoring program.

Alternative Local Strategies

Using the previously discussed sensitive area controls to ensure proper siting and bringing municipal landfills into compliance with the new DWM regulations are the most effective strategies that a local government can pursue to prevent groundwater contamination from landfill leachate. A local government could also consider implementing a program to keep private landfill operators informed of their responsibilities under the new regulations. A locality may also want to implement an education program aimed at discouraging non-regulated hazardous waste generators from disposing hazardous waste into the municipal waste stream. Possible components of such a program are presented in the section on accidental spills and improper disposal of hazardous materials. Another strategy for keeping potential contaminants out of landfills is to develop a comprehensive recycling program. Recyclable materials that may contaminate groundwater if disposed of in landfills include used oil, solvents, plastics and newsprint.

Pesticide and Fertilizer Applications

Existing Regulations and Initiatives

The 1989 Virginia Pesticide Control Act, mandates a number of programs which will help prevent groundwater contamination by pesticides. Under the Act, the Virginia Department of Agriculture and Consumer Services (VDACS) ensures that the regulations of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) are met. These regulations govern the registration, and proper labeling, handling, and use of pesticides. In conformance with FIFRA, the VDACS administers a certification program through which commercial and private pesticide applicators demonstrate their competency in the handling and use of pesticides.

The Pesticide Control Act requires a number of initiatives that go beyond federal mandates. These include:

- The establishment of a State Pesticide Control Board which has broad regulatory powers. This Board has the authority to cancel or deny registration for a pesticide which causes significant degradation of groundwater.

- Creation of a consumer-oriented public education program to encourage the proper use of pesticides and the use of alternative, environmentally safe pest controls.

- An annual business license requirement for commercial firms which sell, distribute, store or apply pesticides. This program would include record keeping and reporting requirements to enable the VDACS to monitor the use purchase, distribution and storage of pesticides.

- Public notification of pesticide use near structures.

- Stricter certification requirements for commercial applicators.

- Stiff penalties for violating the provisions of the Act.

One of the first initiatives undertaken by the Pesticide Control Board has been a pilot "clean day" project through which private and commercial applicators can safely dispose of banned or unwanted pesticides at a central location. The pilot Clean Day is expected to take place in the spring of 1990.

There are no regulations limiting the amount, type or patterns of fertilizer use. Manufacturers of fertilizers must be licensed by the VDACS. Under this program, manufacturers must register their products with VDACS, report fertilizer sales by county, and submit to a VDACS sampling program. The principal objective of this program, however, is consumer, not environmental protection.

As mentioned previously, VCES has included a groundwater protection education program in its agriculture and natural resources educational unit. Fertilizer and pesticide management are important components of this program.

Alternative Local Strategies

The options available to local governments to prevent groundwater contamination from fertilizer and pesticides use are limited. Local regulation is, for the most part, pre-empted by State and federal programs. Also, due to the diffuse nature of fertilizer and pesticide use and the limited resources of local governments, it would be extremely difficult for localities to detect, characterize and resolve potential or existing groundwater contamination problems. Therefore, the most effective way for a locality to address groundwater contamination from pesticides and fertilizers is through a preventive public education program. Such a program should be conducted in conjunction with the existing VCES program and should have separate components for three distinct target audiences: farmers, landscape maintenance businesses, and homeowners. Issues that should be addressed in the design of groundwater education programs for each of the targeted groups are discussed below.

Any education program aimed at reducing the threat of pesticide contamination of groundwater from farming activities should emphasize Integrated Pest Management (IPM). IPM is the use of various environmentally safe biological and cultural controls combined with improved timing and placement of traditional chemical pesticides to reduce overall pesticide use. The three principles of the IPM approach are preventive practices, remedial practices, and the economic threshold. Preventive practices make crops less attractive to, more resistant to, and more competitive with pests. Such practices include crop rotation, timely planting and harvesting, and the use of pest-resistent varieties of plants. Remedial practices include the limited use of traditional chemical controls and the use of "natural" biological controls. Biological control practices use organisms (predators, parasitoids or pathogens) which feed upon or infect insect pests. The third principle of IPM is the economic threshold (ET). The ET is the point at which pest population levels indicate that the additional cost and additional benefit of pesticide application are equal. Only when the economic threshold is approached would pesticide use be considered. At population levels below the economic threshold, application would be a waste of money, time and pesticide.

Besides IPM, an education program to prevent groundwater contamination from the agricultural use of pesticides should stress the following:

- Wherever appropriate, less leachable pesticides should be substituted for those substances on the EPA's list of leachable pesticides.

- Whenever possible, contact pesticides that do not have to be incorporated into the soil should be used.

- Recommended application rates should not be exceeded.

- Pesticide application equipment should be calibrated to ensure that pesticides are applied at intended rates.

- The application rate should be uniform over an entire field. Overlapping should be avoided.

A groundwater protection education program designed for the farming community should address the following points regarding fertilizer application:

- Where appropriate, regular fertilizers should be replaced with slow-release formulations. A slow-release fertilizer geared to a plant's uptake rate can reduce the amount of fertilizer needed.

- Nitrogen applications can be reduced by determining the residual soil nitrates in the crop and rooting zone.

- Nitrate leaching can be reduced by splitting the required amount of fertilizer between two applications and ensuring that applications are made during periods of greatest crop uptake.

- Crop rotation with nitrogen producing legumes can reduce the need for fertilizer.

An education program aimed at reducing the threat of groundwater contamination from fertilizer and pesticide use by homeowners should emphasize the following points:

- Product label instructions pertaining to appropriate use, mixing, application rate, storage, and disposal should be followed carefully.

- When purchasing pesticides and fertilizers, careful consideration should be given to the quantities actually needed. Buying excessive quantities often leads to over- application or improper disposal.

- Local disposal laws should be checked before a pesticide is disposed of in a landfill or trash receptacle. Disposal of excess pesticides at a SPSA hazardous waste collection center should be encouraged.

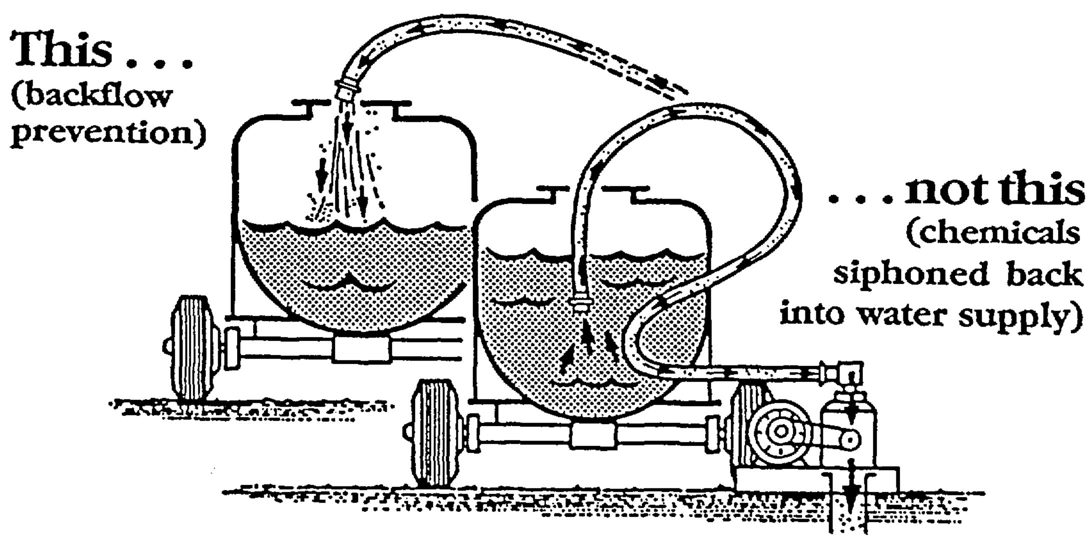
- Homeowners should test their soils to determine the proper type and quantity of fertilizer needed.

- Soil amendments such as compost, manure or mulch can reduce the need for fertilizers by adding nutrients and increasing the soil's nutrient holding capacity.

- Alternatives to pesticides should be encouraged. These include a number of biological and cultural controls similar to those used in IPM.

- When mixing products with a garden hose used with a well pump, care should be taken to avoid back-siphoning into the water supply. Also, excess pesticides or fertilizers should never be dumped into an abandoned well.

BACK-SIPHONING PREVENTION



Source: Virginia Cooperative Extension Service, 1988

Saltwater Encroachment

Existing Regulation and Initiatives

The intrusion or upconing of saltwater into the Columbia and Yorktown-Eastover aquifers is usually attributed to declining groundwater levels caused by either a localized proliferation of wells tapping these aquifers or the dewatering of borrow pits. VWCB policy specifies that "total withdrawals from coastal zone aquifers should be limited to such quantity as to prevent the intrusion of salinity beyond the limit determined acceptable for the beneficial uses of the aquifer."[51] Despite this policy directive, there are no specific State, or federal, regulations which address the saltwater encroachment problem. The Virginia Groundwater Act authorizes the VWCB to govern groundwater use in designated Groundwater Management Areas by requiring permits for withdrawals in excess of 300,000 gallons per month. Such withdrawals, however, are generally from the deeper confined aquifers and do not contribute directly to saltwater encroachment into the shallow aquifers.

Alternative Local Strategies

Given the lack of federal and State regulations, the only practical means of addressing this problem is the development of local management strategies aimed at limiting withdrawals in areas prone to saltwater encroachment. There are a number of technically feasible engineering solutions to preventing saltwater encroachment, but most of these techniques would be too costly for widespread application in Southeastern Virginia localities. For more information on these techniques, the reader is referred to the VWCB Best Management Handbook: Sources Affecting Groundwater.

Under existing State enabling legislation, local cities and counties do not have the power to restrict groundwater usage. Therefore, the most effective strategy to prevent saltwater encroachment would be an educational program which encourages households and businesses dependent on groundwater to follow water conservation practices. Other strategies might include a reinjection ordinance which regulates geothermal heat pump reinjection; a program to extend public water lines into areas with current or potential saltwater encroachment problems; and, as previously discussed, various land use controls which maintain natural recharge rates by minimizing impervious surfaces and/or which guide the siting of borrow pits.

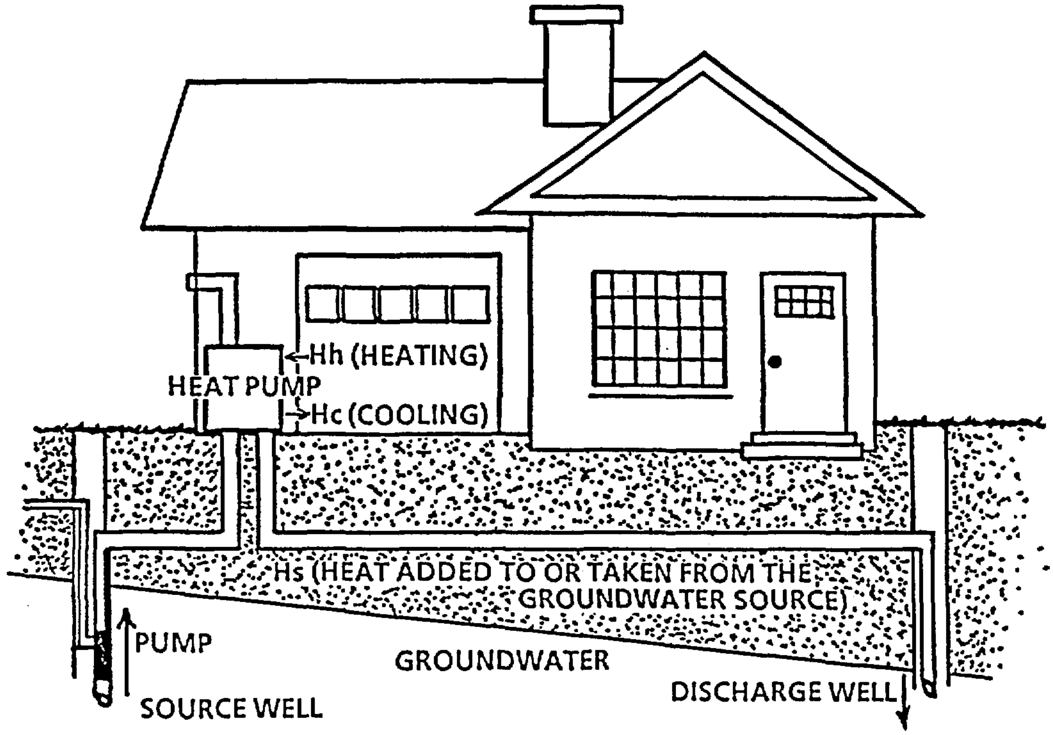
The following points should be emphasized in an education program to encourage groundwater conservation in areas with existing or potential saltwater encroachment problems:

- Household water consumption can be significantly lowered by altering water use behavior. For instance, faucets can be turned off while brushing teeth, shampooing, bathing, washing dishes, and so forth.

- Many plumbing fixtures can be retrofitted or replaced to improve water use efficiency.

- In landscaping, drought-resistant species of plants can reduce the need for yard watering. This approach to landscaping is known as xeriscaping.

- In watering lawns and gardens, drip irrigation is preferred over spray irrigation because it uses less water.



In order to ensure that geothermal heat pumps do not deplete groundwater supplies and encourage saltwater encroachment, a locality might develop an ordinance requiring that any heat pump, not already covered by a NPDES permit, discharge to the aquifer from which it withdrew. It may also be required that no pollutants, such as biocides or other treatment chemicals, be added to the water before it is reinjected. Virginia Beach has adopted such an ordinance.

In areas currently or potentially affected by saltwater encroachment, a locality may find it necessary to replace groundwater supplies with a public water system. If not a scheduled component of a capital improvements program, this may impose a severe financial burden on a locality. In areas where large quantities of groundwater are being used in lieu of public water, replacing groundwater supplies could also put a strain on public water resources. For instance, in Virginia Beach, public water demand projections and the scope of the Lake Gaston Project are based on the assumption that there will be continued dependence on groundwater in many parts of the city. If significant contamination from saltwater encroachment occurs and the City is forced to expand its public water system move rapidly than planned, existing and future water resources may be insufficient to meet demand.

In addition to the above strategies, local governments should work with the VWCB to intensify existing monitoring programs to identify and measure saltwater intrusion. This effort might be supplemented by encouraging homeowners to have their wells privately tested for a number of contaminants, including saltwater.

MODEL GROUNDWATER PROTECTION REGULATIONS

Despite the numerous State and federal initiatives which promote groundwater protection, local government has the greatest potential to affect groundwater quality. This is because localities, using their delegated police powers, are uniquely suited to address local land use activities as they relate to local groundwater conditions. This Handbook has emphasized the importance of designing a local groundwater protection program which is guided by a groundwater protection plan. This plan should contain locally appropriate goals, objectives and management strategies derived from a thorough assessment of local groundwater protection needs. Once a groundwater protection plan has been adopted, local groundwater protection regulations are needed to accomplish plan implementation.

The purpose of this chapter is to present outlines for regulations that might be used to implement a locally adopted groundwater protection plan. Outlines are presented for new septic system management and hazardous material ordinances, and for regulations that might be incorporated into existing zoning, subdivision, erosion and sediment control, site plan review and stormwater management ordinances. Due to the diversity of potential contamination sources within a community, and because contamination threats and protection needs can differ significantly among communities, it was deemed impractical to develop a single, comprehensive model groundwater protection ordinance.

These outlines only present issues that should be considered in drafting regulations and do not recommend numerical operation and design standards. Such standards can only be developed through detailed assessment of local conditions and could exceed minimum State standards where necessary. Even though decisions on what types of regulations to adopt will ultimately be guided by local plans, the model regulations should be widely applicable because they address groundwater contamination problems found throughout much of Southeastern Virginia. The model regulations presented in this Handbook are meant to provide guidance only. Use of any of these regulations will require adapting the language and developing appropriate numerical design and operation standards to meet local needs. In addition, the specific content and language of local regulations should be reviewed by the city/county legal department to ensure consistency with local laws and State enabling legislation.

MODEL SEPTIC SYSTEM MANAGEMENT ORDINANCE

The following outline is for a septic system management ordinance that would build upon existing VDH regulations. A septic system management ordinance could be implemented either jurisdiction-wide or in designated on-site sewage management districts. Numerical siting, design and operating standards are unspecified, but should be adapted to local conditions and exceed State standards where necessary. It is important to note that some of the provisions of this model ordinance are currently under review by the VDH.

Sec. 1. Definition of Septic System. Would probably include conventional septic systems with septic tanks and gravity fed drainfields, and pump systems with a septic tank, pump station and drainfield.

Sec. 2. Minimum Lot Size. Establish minimum lot area and minimum lot width at building line for any lot utilizing a septic system.

Sec. 3. Prohibition of Commercial and Industrial Septic Systems. A commercial and industrial facility would be prohibited from using a septic system unless it meets certain design and operation criteria. These criteria might include the following:

(a) Facility water use must be kept below a specified daily limit.
(b) The septic system must be used for sanitary and food service waste disposal only.
(c) The facility must not utilize or produce any of the substances listed in section 6 of this ordinance.

Sec. 4. Site Restrictions. The following site restrictions could apply to any septic system requiring an on-site wastewater disposal system:

(a) All septic systems must be separated from the water table by a specified minimum distance to ensure that systems remain well above seasonally high water table levels. [Note: the VDH is currently re-evaluating existing State water table separation requirements].
(b) Septic systems are prohibited in soil horizons having an estimated or measured percolation rate in excess of a specified amount. A minimum standoff distance for trench bottoms above any soil layer having an unsatisfactory percolation rate should also be specified.
(c) Septic systems are prohibited in specified soils that are poorly drained; somewhat poorly drained; subject to flooding; have high shrink/swell characteristics (unless certain pre-soaking percolation tests are conducted); or are well drained, but have slow permeability.
(d) Septic systems are prohibited in upland drainage ways.
(e) Septic systems are prohibited where free standing water is present in a profile hole.

Sec. 5. Siting and Construction of Septic Systems. The following standards might be used to govern the siting and construction of any septic system for which a VDH on-site wastewater disposal permit is required:

(a) All septic systems must have a 100 percent reserve drainfield capacity. [Note:This is already required for Chesapeake Bay Preservation Areas].

This reserve drainfield must be able to accommodate a system that meets the site restrictions contained in Section 4.

(b) All septic systems must be separated from tidal waters, free-flowing streams, and impounded water by a specified minimum distance.

(c) All lots must be graded or engineered in such a manner that prevents surface runoff from flowing towards a septic field.

(d) Explosive or pneumatic hammers will not be permitted for the excavation of drainfields or septic tanks.

(e) No storm drain connections to a septic system are permitted.

(f) No irrigation system should be installed within a specified distance from the septic system.

(g) All residential septic systems must be designed to accommodate the disposal of waste from a garbage disposal unit. Disposal units shall be connected to a septic system by a separate septic tank installed between the unit and the primary septic tank. The disposal unit tank must be pumped out at specified intervals.

(h) All septic systems must have sufficient vehicle access and access to the septic tank cover for maintenance purposes.

(i) No portion of a septic system should be located on another lot or parcel unless an easement is recorded.

(j) Any person who constructs a septic system must have a Class B contractors license and be approved by the local health department.

(k) Any construction of a septic system will be preceded by the filing of an as-built drawing of the system with the local health department. This drawing would show 1) the size, orientation and location of each component of the system, and 2) the distances from the system to all structures on the property and to all property lines.

Sec. 6. Prohibited Materials in Septic Systems. Disposal of the following materials might be prohibited in all septic systems: hazardous materials as defined by the National Fire Prevention Code; petroleum products; pesticides; embalming fluids; photography developing fluids; medical wastes; septic tank cleaning compounds; drain cleaners; disposable diapers and coffee grounds.

Sec. 7. Maintenance and Repair of Septic Systems. Septic system owners should have the following maintenance and repair responsibilities:

(a) Every septic system must be kept in good repair so that the system functions as intended.

(b) Septic systems must be pumped and maintained at specified intervals. [Note: CBPA regulations require that septic tanks within Preservation Areas be pumped out every five years]. Immediately upon having a septic system pumped and maintained, the owner of the system must certify in a form approved by the local health department that such pumping and maintenance was performed. Another option is for a locality to implement an on-site inspection program which ensures that owners properly maintain their systems and undertake any necessary corrective actions.

Sec. 8. Enforcement. Enforcement measures should be strong enough to ensure compliance with the provisions of this ordinance. Authority should be granted to the locality to correct any violations that are not corrected by the septic system owner within a specified time. The septic system owner would then be responsible for reimbursing the locality for the cost of correcting the violation and for any administrative expenses.

MODEL HAZARDOUS MATERIAL STORAGE ORDINANCE

A number of State and federal regulations govern the storage, treatment and disposal of hazardous wastes. The storage and use of hazardous materials prior to their ultimate disposal as waste is virtually unregulated, however. Such substances can contaminate groundwater and surface water through the infiltration of material spills or by runoff from storage and production areas. The following ordinance, which is an adaptation of a model ordinance prepared by the Conservation Law Foundation of New England, might be implemented by a locality to prevent such occurrences. This ordinance would also be useful in implementing a stormwater management program. It could also be used to meet and supplement the emergency planning and community right to know requirements of SARA Title III.

Sec. 1. Definitions.

(a) "Hazardous Material" means any substance or mixture of substances having physical, chemical or infectious characteristics which pose significant actual or potential threats to the environment or to human health if discharged. "Hazardous materials" include, without limitation, organic chemicals, petroleum products, heavy metals, radioactive or infectious wastes, acids or alkalies, pesticides, herbicides, solvents and thinners.

(b) "Discharge" means the accidental or intentional spilling, leaking, pumping, pouring, emitting, emptying, or dumping of hazardous materials upon or into any lands or waters.

Sec. 2. Prohibitions.

(a) The discharge of hazardous materials is prohibited.

(b) Outdoor storage of hazardous materials is prohibited, except in product-tight containers which are protected from the elements, leakage, accidental damage and vandalism, and which are stored in accordance with the provisions of Section 3.

Sec. 3. Storage Controls, Registration, and Inventory.

(a) Every owner or operator of a site at which hazardous materials are stored in quantities totaling more than a specified number of liquid gallons or a specified number of pounds dry weight shall register with the local health or fire department the types, quantities, location and method storage of these materials. The health or fire department may require that an inventory of such materials be maintained on the premises and be reconciled with purchase, use, sales, and disposal records on a monthly basis to detect any product loss.

(b) The health or fire department may require that containers of hazardous materials be stored on impervious, chemical resistant surfaces that are compatible with the materials being stored, and that design best management practices be used to ensure product containment. These practices might include enclosing storage areas, and providing berms, curbs and specialized drains and sumps to prevent release of contaminants.

Sec. 4. Reporting of Discharge. Any person having knowledge of a discharge of hazardous material believed to be in excess of a specified amount must immediately report the discharge to the health or fire departments, or other public safety agency.

Sec. 5. Enforcement

(a) The health or fire department and its agents may enter upon privately owned property to inspect for compliance with this ordinance.

(b) Upon request of an agent of the health or fire department, the owner or operator of any site using or storing hazardous materials must furnish all information required to enforce and monitor compliance with this ordinance.

(c) Certification of conformance with the requirements of this ordinance shall be required prior to issuance of construction and occupancy permits for any nonresidential use.

(d) Any person who violates any provision of this ordinance shall be punished by a specified fine. Each day or portion thereof during which a violation continues constitutes a separate offense.

Sec. 6. Fees. Any person registering storage of hazardous materials pursuant to Section 4 shall pay an annual registration fee based on the number of gallons or pounds of hazardous materials stored.

AMENDMENTS TO EXISTING ZONING ORDINANCE

The following sensitive area overlay zone provisions might be incorporated into an existing zoning ordinance. These provisions were adapted from the Spokane

County, Washington Aquifer Sensitive Area Overlay Zone Ordinance. These provisions would also be used to help implement a stormwater management program and to meet or supplement SARA Title III requirements.

Sec. 1. Intent. The intent of this sensitive area overlay zone is to provide supplemental development regulation in the designated sensitive area to protect groundwater resources from additional long-term contamination originating from man's activities. These provisions could apply to any person, firm, or corporation within a sensitive area that proposes to establish a new or different land use or activity.

Sec. 2. Objectives.

(a) To allow use, handling or storage of hazardous materials and to assure adequate protection of groundwater;
(b) To establish strict performance standards for use, handling or storage facilities associated with hazardous materials so as to prevent their introduction into the groundwater supply;
(c) To establish land use intensity limitations, particularly sanitary sewers;
(d) To prohibit the disposal of hazardous materials within designated sensitive areas;
(e) To alert landowners, potential buyers, appraisers and lessees of the legal restrictions associated with certain land use activities in the overlay zone.

Sec. 3 Administrative Guide for Implementation of the Sensitive Area Zone.

(a) A Hazardous Materials Handbook would be essential to the implementation of these provisions. This handbook would describe suggested management and design solutions to achieve the performance standards contained in Section 5.
(b) A Hazardous Materials List would be developed and used in the initial screening of applications in order to anticipate the types and quantities of chemicals associated with various activities. This list would include the names, amounts and storage techniques commonly associated with chemicals used in various activities.

Sec. 4. Application of Sensitive Area Overlay Zone Standards. This section would describe:

(a) The responsibilities of different city/county agencies in implementing these provisions.
(b) The process that would be used to determine whether hazardous materials would be used in a new land use or activity.
(c) Procedures for assuring compliance with these provisions.

Sec. 5. Standards for Business, Commercial, and Industrial Uses within Sensitive Areas.

(a) In areas not served by public sanitary sewers, all business, commercial and industrial developments regardless of hazardous materials usage whose wastewater disposal needs exceed those of an average single dwelling unit must be served by wastewater disposal systems that provide sensitive area protection equal to or greater than that listed below:

(i) Collection or treatment using sealed lagoons;
(ii) Collection and treatment utilizing holding tanks, and transport/disposal at a site licensed for the particular effluent;
(iii) Collection, treatment and disposal using an appropriate discharge permit;
(iv) Approved connection to an existing public or private collection/treatment facility.

(b) In areas served by public sanitary sewers all uses listed in (a) that do not use hazardous materials shall be connected to the central sewer system.
(c) In areas served by public sanitary sewers all uses listed in (a) that use hazardous materials must be connected to a central sewer system or be subject to the provisions of Section 5(a)(i) through (iii).
(d) All business, commercial and industrial activities and land uses using hazardous materials must meet the following conditions:

(i) Facilities will be designed so that any spilled or leaked materials are contained on-site;
(ii) Facilities will be designed so that any spilled or leaked materials cannot infiltrate the ground;
(iii) No permanent disposal of any waste containing hazardous materials will be allowed on-site.

(e) All activities or land uses using hazardous materials must have specially designed stormwater runoff drainage facilities in areas where spills might occur which are designed to:

(i) Prevent the co-mingling of stormwater runoff and hazardous material spills;
(ii) Enhance spill cleanup procedures; and
(iii) Be consistent with the standards in Section 5(a)(i) through (iv).

Sec. 6. Standards and Conditions for Residential Development in Sensitive Areas.

(a) In areas not served by a public sanitary sewer system residential development shall occur at no less than a specified number of acres per dwelling unit unless the development is served by a sewage disposal system that provides sensitive area protection equal to or greater than that listed in Section 5(a)(i) through (iv).

Sec. 7. Solid Waste and Septic Tank Sludge Disposal within the Sensitive Area. No new sanitary landfill or septic tank sludge disposal sites shall be allowed within the sensitive area. Surface or subsurface disposal of hazardous materials is specifically prohibited in the sensitive area overlay zone.

Sec. 8. Penalty. This section would describe the fines or prison terms resulting from non-compliance with these provisions.

AMENDMENTS TO EXISTING SUBDIVISION ORDINANCE

The following provisions might be included in an existing subdivision ordinance to address groundwater protection issues.

Sec. 1. Intent. To ensure that consideration is given to groundwater quality and quantity during the subdivision process.

Sec. 2. Subdivision Plan Submission Requirements.

(a) Existing and proposed system of drainage systems.
(b) Zoning classification of all land including any sensitive area overlay zones.
(c) Soil data from existing surveys and/or from test pits or borings.
(d) Maximum and minimum water table elevation and direction of groundwater flow.

Sec. 3. Groundwater Impact Analysis. See Section 2 of the suggested amendments to a site plan review ordinance.

Sec. 4. Design Standards.

(a) Subdivision design shall reduce, to the extent possible, the dimensions of impervious areas, including streets.
(b) Subdivision design shall maintain, to the extent possible, pre-development runoff and vegetative cover conditions. In designated sensitive areas, peak stream flows and runoff at the boundaries of the development must be no higher than pre-development levels during a specified design year storm event. In other areas, peak stream flows and

runoff should be no more than a specified percentage higher during the same storm event.

(b) Leak-tight designs shall be used in sanitary sewer construction to prevent groundwater contamination.

(d) The City/County may require the subdivision plan to leave designated sensitive areas in open space for future acquisition by the City/County.

AMENDMENTS TO EXISTING EROSION AND SEDIMENT CONTROL ORDINANCE

The following revisions might be made to an existing erosion and sediment control plan.

Sec. 1. Intent. To ensure that a land disturbing activity does not contaminate local groundwater.

Sec. 2. Erosion and Sediment Control Plan. In addition to other types of information required, a plan for erosion and sediment control plan might include the following:

(a) A description of site-specific hydrogeology including depth to seasonally high and low water table; composition of the soil and unsaturated zone; and groundwater flow characteristics.

(b) All proposed construction practices that may affect groundwater quality or levels shall be identified, and proposed mitigation strategies shall be described. Such practices might include, but are not limited to:

(i) Excavation below the seasonally high water table;

(ii) Disturbance of hazardous wastes left from previous development;

(iii) Use of herbicides and pesticides during clearing and grubbing;

(iv) The stockpiling and use of hazardous materials that may contaminate groundwater.

(c) All proposed erosion and sediment control best management practices that may affect groundwater quality or levels shall be identified, and mitigation strategies shall be described.

AMENDMENTS TO EXISTING SITE PLAN REVIEW ORDINANCE

The following requirements might be incorporated into a site plan review ordinance to protect designated sensitive areas. These provisions were adapted from the West Whitehead Township, Pennsylvania Carbonate Area District Ordinance.

Sec. 1. Intent. To protect a designated groundwater sensitive area from land use and development patterns that would threaten the quantity and quality of groundwater.

Sec. 2. Groundwater Impact Analysis. Prior to any change in land use within a designated sensitive area, a developer would submit a groundwater impact analysis which includes the items listed below. [Note: This analysis may also be incorporated into a subdivision ordinance. Also in developing local regulations for Chesapeake Bay Preservation Areas, consideration should be given to incorporating this analysis into the existing water quality impact assessment requirements].

(a) A map no less detailed than 1" = 100" (or scale normally required) indicating the location of the property and all proposed improvements thereon.

(b) A description of the proposed action including: types, locations, and phasing of proposed site disturbances and construction, and proposed future ownership and maintenance of the property.

(c) For developments with proposed grading, construction of buildings and other improvements, the submission of site-specific information describing geology, topography, groundwater and surface water hydrology, soil types, vegetative cover and existing improvements and uses.

(d) A map indicating existing drainage, a description and map of proposed stormwater management improvements, and a post-development water budget analysis.

(e) A map showing the existence of existing private and public wells on adjoining properties, and the on-site location and extent of any of the following, if existing or proposed:

(i) Underground storage tanks;

(ii) Fill containing any material that would represent a potential contamination hazard to groundwater and surface water;

(iii) Facilities for storing, handling, processing or disposing of hazardous materials;

(iv) Land grading or construction activities that would directly or indirectly affect natural groundwater flow.

(f) A description of all proposed measures to control all adverse groundwater quality impacts that may occur as a result of the proposed action.

AMENDMENTS TO EXISTING STORMWATER MANAGEMENT ORDINANCE

The following sections might be added to an existing stormwater management ordinance. These provisions were partially adapted from the Virginia Beach Stormwater Management Ordinance.

Sec. 1. Intent. To maintain or restore the groundwater quantity by preserving natural groundwater flow hydraulics of an area, and to maintain groundwater quality by ensuring that stormwater management practices do not pollute groundwater.

Sec. 2. Stormwater Management Plan. In addition to other types of information needed to assess stormwater impacts, a stormwater management plan might require the following relating to groundwater:

(a) Pre-development conditions including:

(i) the location of areas on the site where stormwater collects or percolates into the ground;
(ii) Groundwater levels including seasonal fluctuations;
(iii) topography and soils.

(b) Proposed alterations including:

(i) changes in topography;
(ii) areas that will be covered with impervious surface and a description of the surfacing material.

(c) Predicted impacts of the proposed development including:

(i) changes in groundwater quality;
(ii) changes in groundwater levels;

(d) Proposed stormwater management devices including:

(i) areas of a site to be used or reserved for percolation.

Sec. 3. Performance Standards.

(a) Stormwater management systems shall be designed to protect natural groundwater quality and groundwater levels.
(a) All developments must be designed to preserve present natural drainage patterns and local groundwater recharge conditions. This requires that all drainage systems be designed to recharge to groundwater as closely as possible to the point where stormwater falls.

(b) Development intensities and associated local area drainage design in designated sensitive areas shall be capable of complete local recharge of a specified design year storm.

Sec. 4. Design Standards.

(a) Stormwater infiltration devices shall be built above the seasonally high water table;

(b) Where necessary, stormwater detention facilities shall be constructed with clay liners to prevent the infiltration of polluted stormwater runoff into the water table.

IMPLEMENTATION CONSIDERATIONS

In evaluating the feasibility of the model groundwater protection regulations presented in this chapter, careful consideration must be given to whether local capability exists for successful implementation. The studies necessary to adapt the suggested regulations to local conditions, and the review, monitoring, inspection and enforcement provisions contained in the regulations will undoubtedly require significant increases in funding for staffing, training and equipment. At present, there is little State or federal financial assistance available for local groundwater protection activities. It is therefore essential that programs be designed to make the most of available resources.

To avoid duplication of effort and to make the most efficient use of limited resources, localities should, wherever possible, coordinate groundwater protection activities with other management programs. For example, groundwater protection regulations which address hazardous material management would also be of benefit in achieving stormwater management and SARA Title III objectives. Another opportunity for program coordination lies in the local implementation of the Chesapeake Bay Preservation Act regulations. Local CBPA programs might be expanded to include the designation of groundwater sensitive areas and the implementation of groundwater protection strategies.

To ensure effective planning and implementation of a local groundwater protection program, all entities with groundwater use and/or protection concerns should be involved. These entities might include all local, State and federal agencies with groundwater management responsibilities; private industry; environmental groups; and homeowners dependent on private wells and/or septic systems. One way of ensuring involvement from these groups would be the creation of a groundwater protection council or task force. This group might coordinate planning efforts, serve as a vehicle for public participation, guide policy making, review development projects that may impact groundwater, monitor State and federal regulatory activities relating to groundwater management, and communicate ongoing work to their constituencies.

CONCLUSION

Despite the long-recognized importance of a dependable groundwater supply to Southeastern Virginia's economy and quality of life, existing and potential contamination threats to this resource have only recently become a matter of concern. It has long been assumed that, due to its physical location, groundwater was generally protected from pollution and that any pollutants introduced on or into the ground would be attenuated by natural processes. Although this assumption is valid under certain circumstances, research and documented contamination incidents have demonstrated that groundwater can be extremely susceptible to pollution and that such contamination incidents can have disastrous consequences for a community.

To date, Southeastern Virginia has been fortunate enough to avoid widespread contamination of its groundwater supply. The overall quality of the resource is good. However, a number of localized contamination incidents from a variety of sources have been documented and the number of reported groundwater contamination incidents has been increasing rapidly. Moreover, due to the difficulties in detecting and assessing contamination, it is generally assumed that a significant number of incidents have gone undiscovered. Given the region's pace of development and the the proliferation of potential groundwater contamination sources, it is imperative that local governments become more involved in protecting local groundwater resources.

The intent of this Handbook is to help localities use the powers available to them to develop programs which will anticipate and prevent groundwater contamination. It is essential that local governments implement protection programs now while overall quality of local groundwater resources is still good. Efforts to clean up contaminated groundwater can be extremely expensive, or perhaps impossible. By ignoring groundwater protection, Southeastern Virginia localities may someday be faced with contamination problems that pose health threats to their citizens and present obstacles to economic development. Effective local groundwater protection program implemented in concert with State and federal management programs will ensure that Southeastern Virginia's groundwater supply will remain a safe, renewable resource that will serve the region indefinitely.

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GLOSSARY

Aquifer

A geologic formation, a group of formations or a part of a formation that contains sufficient permeable material to yield sufficient quantities of water to wells and springs.

Aquitard

An impermeable or semi-permeable geologic formation that hampers the movement of water into or out of a confined aquifer; also called a confining bed.

Area of Influence

The surface area which overlies a well's cone of depression.

Artesian Well

A well tapping a confined aquifer in which the static water level is above the top of the aquifer. A flowing artesian well is a well in which the water level is above the land surface.

Attenuation

The dissipation of pollutants during infiltration through a variety of processes including filtration, sorption, oxidation and reduction, biological decay and assimilation, buffering of acidic and alkaline materials, chemical precipitation, volitization, evaporation and radioactive decay.

Biological Decay and Assimilation

The process by which plant uptake and microbial decomposition removes or renders inert inorganic or organic contaminants.

Buffering

The ability of a substance to maintain a constant pH over a wide range of concentrations.

CBPA

Chesapeake Bay Preservation Act

CERCLA

Comprehensive Environmental Response, Compensation, and Liability Act; also known as "Superfund".

Chemical Precipitation

The process by which a soluble substance is separated out of a solution.

Coastal Plain

A physiographic province in the eastern part of Virginia characterized by gently dipping unconsolidated sands, silts and clays.

Columbia Aquifer
The unconfined water table aquifer in Southeastern Virginia.

Cone of Depression
Depression in the potentiometric surface that develops around a well, or well field, from which water is being drawn.

Confined Aquifer
An aquifer that is enclosed between impermeable or semi- permeable geologic formations. Water in this aquifer is under pressure that is significantly greater than atmospheric pressure.

Consolidated Formations
Geologic formations comprised of solid or hardened rock masses.

Dilution
A process which, through the introduction of water by precipitation or other source, causes the concentration of a containmant to decrease with distance from the point of introduction.

Discharge
The movement of water from an aquifer to springs, seeps, marshes, surface waters, or flowing or pumping wells.

Discharge Area
The area in which groundwater discharge occurs.

DMME
Virginia Department of Mines, Minerals and Energy

DRASTIC
A mapping methodology through which the groundwater pollution vulnerability of various hydrogeologic settings is determined.

DWM
Virginia Department of Waste Management

EPA
U.S. Environmental Protection Agency

Evaporation
The change in a substance's physical state from liquid to gaseous vapor.

Evapotranspiration
The release of water from the earth's surface to the atmosphere by evaporation from soil and surface water, and by transpiration from plants.

Fall Line
An imaginary north-south line in Virginia where abrupt changes in geology and elevation mark the transition between the Coastal Plain and the Piedmont Plateau.

FIFRA
Federal Insecticide, Fungicide, Rodenticide Act

Filtration
A process through which contaminants larger than the pore spaces of the host median are removed.

Groundwater
All water beneath the earth's surface, as distinct from surface water.

GWPSC
Virginia Groundwater Protection Steering Committee

HSWA
1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act.

Hydraulic Conductivity
See Permeability.

Hydrogeologic Setting
The composite description of all hydrogeologic factors influencing groundwater movement within an area.

Hydrogeology
The science that deals with subsurface waters and related geologic aspects of surface waters.

Hydrologic Cycle
A continuous movement of water from the atmosphere to the surface of the earth and back to the atmosphere through various processes including precipitation, runoff, infiltration, percolation, storage, evaporation and transpiration.

Hyporheic Zone
The area below a stream channel which is hydrologically and ecologically connected to the stream.

Infiltration
The movement of water from the surface into the ground.

IPM
Integrated Pest Management

Landfill
A system of garbage and trash disposal in which waste is buried between layers of earth.

MGD
Millions of Gallons per Day

MSL
Mean Sea Level

NPDES
National Pollutant Discharge Elimination System

Outcrop Area
That portion of geologic formations, including aquifers, that is exposed at the earth's surface.

Overlay Zone
A zone that is superimposed on existing zoning districts to provide additional land use regulations.

Oxidation
Chemical reaction in which there is a transfer of electrons from an ion or atom, thus increasing its net charge or valence.

Percolation
Subsurface movement of water through openings in porous earth material.

Performance Standards
A land use planning technique through which the type and intensity of a land use is determined by the ability of a development to meet certain performance criteria.

Permeability
Measure of an aquifer's ability to transmit water, generally expressed in feet of groundwater per day.

Piezometric Surface
See Potentiometric Surface.

Planned Unit Development (PUD)
A land use planning technique through which subdivision and zoning regulations apply to an entire project rather than to individual lots.

Porosity
The ratio of pore space in a geologic formation to the total volume of material.

Potentiometric Surface
An imaginary surface defined by the level to which groundwater will rise if released from a confined aquifer by a well or conduit; also known as piezometric surface.

PReP
The Virginia State Water Control Board Pollution Remediation Program

Radioactive Decay
The spontaneous transformation of one atomic nucleus into another, accompanied by the emission of subatomic particles or gamma rays.

Recharge
The addition of water to the groundwater system by natural or artificial processes.

Recharge Area
The surface area in which recharge occurs.

RCRA
Resource Conservation and Recovery Act

Reduction
Chemical reaction in which there is a transfer of electrons to an ion or atom, thus decreasing its net change or valence.

Relict Sand Ridge
A subsurface sand formation developed under a climate and/or geologic condition different from those prevailing at present.

Saltwater Intrusion
The lateral invasion of a freshwater aquifer by saltwater from adjacent surface water.

Saltwater Upconing
A process through which saline water underlying freshwater in an aquifer rises upward into the freshwater zone as a result of pumping.

SARA
Superfund Amendments and Reauthorization Act.

Saturated Zone
: A subsurface zone in which all pores or voids are filled with water under pressure greater than that of the atmosphere; the zone in which groundwater occurs.

SDWA
: Safe Drinking Water Act

Soil
: The weathered unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of vegetation.

Sorption
: Process by which substances are taken up or held by absorption or adsorption.

SPSA
: Southeastern Public Service Authority

Surface Impoundments
: Ponds or lagoons used by industries, agricultural operations and municipalities for the retention, treatment and/or disposal of hazardous and non-hazardous liquid wastes.

SVGMA
: Southeastern Virginia Groundwater Management Area

SVPDC
: Southeastern Virginia Planning District Commission

SWCL
: State Water Control Law

Synthetic Organic Compound
: Manufactured compounds of carbon chains or rings containing hydrogen, and with or without oxygen, nitrogen, and other elements.

THB
: Virginia Department of Emergency Services Technological Hazards Branch.

Topography
: The slope and slope variability of the land surface.

Transfer of Development Rights (TDR)

A land use planning technique through which property owners in designated areas may transfer (sell) development rights granted to them under a zoning ordinance to property owners in area where conditions for development are more appropriate.

Unconfined Aquifer

An aquifer not confined by an overlying impermeable layer. The water table defines the upper limit of an unconfined aquifer.

Unconsolidated Formations

Geologic formations in which individual particles are not bound strongly enough together to form rocklike material.

Unsaturated Zone

A subsurface zone in which pores or voids are only partially filled with water; usually the interval between the land surface and the water table (also called the zone of aeration or the vadose zone).

USGS

United States Geological Survey

UST

Underground Storage Tank

Vadose Zone

See Unsaturated Zone.

Volatilization

The loss of a compound to the atmosphere.

VCES

Virginia Cooperative Extension Service

VDACS

Virginia Department of Agriculture and Consumer Services

VDES

Virginia Department of Emergency Services

VDH

Virginia Department of Health

VPA Permit

Virginia Pollution Abatement Permit

VWCB

Virginia State Water Control Board

Water Table

The upper limit of the saturated zone in an unconfined aquifer.

Yorktown-Eastover Aquifer

The uppermost confined aquifer in Southeastern Virginia.

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APPENDIX A

EXAMPLES OF ECONOMIC COSTS RESULTING FROM CONTAMINATED GROUNDWATER[1]

Location	Contaminants	Nature of Costs	Direct Costs Incurred[2]
Canton, CT	Carbon tetrachloride, methylethylketone, trichloroethylene, chloroform	Well closings, extension of water lines to affected areas	$145,000 - $379,000
Oscoda, MI	Trichloroethylene	Well closings, provision of new source of water	$140,000
South Brunswick, NJ	Chloroform, toluene, xylene, trichloromethane, trichloroethylene	Well closings, extension of water lines to affected areas.	$300,000
Cohansey Aquifer, NJ	Wastes from manufacture of organic chemicals, plastics, resin	148 well closings; removal of drums; interim emergency water supply; drilling of new wells;extension of public water supply	$417,000 (avg. residential water bill increased by 66%)
Miller County, AR	Brine Contamination from oil and gas activities.	Loss of irrigation well Partial rice crop loss Estimated loss in profits from change to non-irrigated crops	$4000 $36,000 $150/acre/year for rice $35/acre/year for cotton $20/acre/year for soybeans
38 communities in 11 midwestern states	Mineral content[3]	Reduced service lives of household plumbing and appliances	Increased annual capital cost per household of 40% as total dissolved solids increased from 250 ppm to 1,750 ppm
Atlantic City, NJ	Chemical wastes	New well field Alternative water supply	$2 million 250,000

EXAMPLES OF ECONOMIC COSTS RESULTING FROM CONTAMINATED GROUNDWATER

Location	Contaminants	Nature of Costs	Direct Costs Incurred
Orange County, CA	Mineral Content[3]	Reduced service lives of household plumbing and appliances	$6.5 million (est. tot. annual capital cost)
Montana	Salinity	Cost of water softeners or cleaning products Loss of farm income	$12.3 million (estimated avg.annual cost) $5 million/year
San Joaquin Valley, CA	Salinity	Loss of farm income	$31.2 million/year
Auburn, MA	Unspecified Chemicals	Alternative water supply for affected area	$180,000
Lathrop, CA	Pesticides	Purchase of water by residents Connection to district water supply	$3-5 per 5 gallons $150/connection, $4-$10 monthly operating costs
Jackson Township, NJ	Chloroform, methylchloride benzene, toluene, trichloroethylene, ethylbenzene, acetone	Estimated cost of water system to replace 100 wells	$1.2 million
Jefferson County, CO	Uranium ore	Alternative water supply and water purification system	$612,000 (1983)
Roanoke, VA	Chromium, cyanide	Alternative water supply for affected area	$1.45 million

EXAMPLES OF ECONOMIC COSTS RESULTING FROM CONTAMINATED GROUNDWATER

Location	Contaminants	Nature of Costs	Direct Costs Incurred
York County, VA	Fly ash containing copper, nickel, beryllium, vanadium, selenium and arsenic	Alternative water supply for 30 well users and capping, sealing and draining of ash pit	$14 million
Clark County, VA	Nitrates, phenols and herbicides	Alternate water supply for affected area	$1.3 million (1981)

Notes:

1. Not included are costs incurred to clean up groundwater contamination.
2. Cost figures are not in constant dollars. Since the examples used occurred over a period of about 25 years, costs in 1989 dollars could be considerably higher.
3. Mineral contamination is generally derived from natural sources. However, artificial recharge may induce mineral contamination through accelerated leaching.

Source: Congress of the United States, Office of Technology Assessment. Protecting the Nation's Groundwater from Contamination, Volume I, Washington, D.C.: OTA, 1984, p. 39.

Southeastern Virginia Planning District Commission, 1989.

APPENDIX B

SUMMARY OF FEDERAL LEGISLATION PERTAINING TO GROUNDWATER PROTECTION IN SOUTHEASTERN VIRGINIA

Legislation	Relevance to Groundwater Protection
Safe Drinking Water Act	Establishes drinking water standards; requires state underground injection control programs; requires federal review of federally assisted projects overlying sole source aquifers; requires states to develop wellhead protection programs; and provides funding for demonstration programs designed to identify critical aquifer protection areas.
Resource Conservation and Recovery Act	Establishes a "cradle to grave" management system for hazardous waste disposal facilities; bans open dumps; provides for state solid waste plans; and sets criteria for solid waste disposal to avoid groundwater pollution. Amendments to this Act in 1984 established a program to control underground storage tanks containing regulated substances.
Comprehensive Environmental Response Compensation and Liability Act	Authorizes the EPA to conduct short-term emergency and long-term remedial actions in response to the release of hazardous substances into the environment.
Hazardous Materials Transportation Act	Establishes regulations for the transportation of hazardous materials, including hazardous wastes.
Hazardous Liquid Pipeline Safety Act	Establishes regulations for the interstate and international movement of hazardous liquids by pipeline (and their storage incidental to such movement).
The Federal Insecticide Fungicide and Rodenticide Act	Establishes regulations for pesticide use and disposal. Also gives the EPA authority to review the environmental effects associated with pesticide use.
Toxic Substances Control Act	Authorizes the EPA to control the manufacture, use and disposal of toxic pollutants. Requires manufacturers to register chemicals, submit periodic reports, and meet labeling and packaging requirements.

SUMMARY OF FEDERAL LEGISLATION PERTAINING TO GROUNDWATER PROTECTION IN SOUTHEASTERN VIRGINIA

Legislation	Relevance to Groundwater Protection
Clean Water Act	Establishes water quality monitoring programs, ongoing water quality and management programs, and water quality standards.
Coastal Zone Management Act	Authorizes funding to encourage and assist states in the development and implementation of programs to manage the use of land and water in the coastal zone.
National Environmental Policy Act	Requires evaluation and study of all federal actions for their potential adverse effects on the environment.

Source: Congress of the United States, Office of Technology Assessment. Protecting the Nation's Groundwater from Contamination, Volume I, Washington, D.C.: OTA, 1984, p. 216.

APPENDIX C

State Anti-Degradation Policy for Groundwater

If the concentration of any constituent in groundwater is less than the limit set forth by groundwater standards, the natural quality for the constituent shall be maintained; natural quality shall also be maintained for all constituents, including temperature, not set forth in groundwater standards. If the concentration of any constituent in the groundwater exceeds the limit in the standard for the constituent, no addition of that constituent to the naturally occurring concentration shall be made. Variance to this policy shall not be made unless it has been affirmatively demonstrated that a change is justifiable to provide necessary economic or social development, that the degree of waste treatment necessary to preserve the existing quality cannot be economically or socially justified, and that the present and anticipated uses of such water will be preserved and protected.

GROUNDWATER STANDARDS APPLICABLE STATEWIDE

Constituent	Concentration	
Sodium	270	mg/1
Foaming Agents as methylene blue active substances	0.05	mg/1
Petroleum hydrocarbons	1.0	mg/1
Arsenic	0.05	mg/1
Barium	1.0	mg/1
Cadmium	0.0004	mg/1
Chromium	0.05	mg/1
Copper	1.0	mg/1
Cyanide	0.005	mg/1
Lead	0.05	mg/1
Mercury	0.00005	mg/1
Phenols	0.001	mg/1
Selenium	0.01	mg/1
Silver	None	
Zinc	0.05	mg/1
Chlorinated Hydrocarbon Insecticides		
Aldrin/Dieldrin	0.003	ug/1
Chlordane	0.01	ug/1
DDT	0.001	ug/1
Endrin	0.004	ug/1
Heptachlor	0.001	ug/1
Heptachlor Epoxide	0.001	ug/1
Kepone	None	
Lindane	0.01	ug/1
Methoxychlor	0.03	ug/1
Mirex	None	
Toxaphene	None	

GROUNDWATER STANDARDS APPLICABLE STATEWIDE

Constituent	Concentration	
Chlorophenoxy Herbicides		
2,4-D	0.1	mg/1
Silvex	0.01	mg/1
Radioactivity		
Total Radium (Ra-226 & Ra-228)	5	pCi/1
Radium 226	3	pCi/1
Gross Beta Activity*	50	pCi/1
Gross Alpha Activity (excluding Radon & Uranium)	15	pCi/1
Tritium	20,000	pCi/1
Strontium-90	8	pCi/1
Manmade Radioactivity - Total Dose Equiv, **	4	mrem/yr

PCi/1 = picocurie per liter
Mrem/yr = millirems per year

*The gross beta value shall be used as a screening value only. If exceeded the water must be analyzed to determine the presence and quanity of radionuclids to determine compliance with the tritium, strontium, and manmade radioactivity standards.

**Combination of all sources should not exceed total dose equivalent of 4 mrem/year.

Source: Virginia State Water Control Board, 1989.

GROUNDWATER STANDARDS APPLICABLE BY STATE

PHYSIOGRAPHIC PROVINCE

CONSTITUENT	CONCENTRATION			
	Coastal Plain	Piedmont and Blue Ridge	Valley and Ridge	Cumberland Plateau
pH	6.5 - 9	5.5 - 8.5	6 - 9	5 - 8.5
Ammonia Nitrogen	0.025 mg/1	0.025 mg/1	0.025 mg/1	0.025 mg/1
Nitrite Nitrogen	0.025 mg/1	0.025 mg/1	0.025 mg/1	0.025 mg/1
Nitrate Nitrogen	5.0 mg/1	5.0 mg/1	5.0 mg/1	0.5 mg/1

Source: Virginia State Water Control Board, 1989.